ACTA PHYTOGEOGRAPHICA SUECICA 66
EDIDIT
SVENSKA VÄXTGEOGRAFISKA SÄLLSKAPET

Eva Waldemarson Jensén

Successions in relationship to lagoon development in the Laitaure delta, North Sweden

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Almqvist & Wiksell International, Stockholm

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Suggested citation: Waldemarson Jensén, E. 1979, Successions in relationship to lagoon development in the Laitaure delta, North Sweden. Acta Phytogeogr. Suec. 66. Uppsala.

Doctoral dissertation at Uppsala University, Sweden 1979.

ISBN 91-7210-066-4 (paperback)
ISBN 91-7210-466-X (cloth)

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Svenska Växtgeografiska Sällskapet
Box 559, S–751 22 Uppsala

Editor: Erik Sjögren
Technical editor: Gunnel Sjörs

Printed in Sweden 1979 by
Borgströms Tryckeri AB, Motala

To
Johanna
and
Annika

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https://archive.org/details/IA41549218_0034

Preface

The Laitaure delta is one of the most valuable features of Swedish nature, and was investigated at the turn of the century and later by Axel Hamberg, whose unique photographs have served as a starting point in tracing vegetational changes in the delta. A more recent geomorphological treatise was published by Valter Axelsson.

Vegetational investigations in the Laitaure delta were started in 1970. The aim was to study the dynamics and successional stages of the vegetation and the abiotic and biotic factors involved in this development. During 1970 to 1974 I worked in the field for about two months each summer and altogether 4 weeks during the winter. In this paper the treated part of the delta vegetation and its development is situated along the lagoon shores, from the levee crest to the open water of the lagoon. Although the birch vegetation of drier sites is treated in a few cases, the main interest lies in the willow and swamp vegetation.

The methods are not described in a single chapter but in parts of chapters 2, 4, 5 and 6. In chapter 2 a survey of the area is given and in chapter 3 the formation of lagoons is treated, a factor of great importance for the vegetation development. Descriptions of the development of different lagoons are found in chapters 5 and 7. The reason for this arrangement will be clear from the list of contents. Some discussions are found together with the presentation of the results, in chapters 6 and 7 and above all in chapter 8.

Apart from Hamberg's old photographs, and unless stated otherwise, all the photos reproduced in this paper were taken by the author. Since most of the old photos were taken from Mt. Skerfe, thus from the north, maps and photos of the delta in the present work are mostly reproduced with south at the top of the page.

The nomenclature follows Lid 1974 (vascular plants), Nyholm 1954–1969 (mosses) and Arnell 1956 (hepatics).

Areas smaller than 0.5 ha have not been mapped unless they have been considered of the utmost interest.

This investigation was encouraged by Hugo Sjörs, head of the Institute of Ecological Botany, Uppsala. Besides discussing problems during a visit to the area of investigation, he aided the development of this thesis by constructive critical comments. Håkan Hytteborn has revised the manuscript and given much valuable advice. I wish to express my sincere gratitude for their patience and never-failing interest in my work.

During the course of this investigation Valter Axelsson, Department of Physical Geography, Uppsala, provided me with material and data and also critically read parts of the manuscript. Valuable advice and suggestions have been received from Eddy van der Maarel, University of Nijmegen, Holland, who also encouraged the completion of this work.

Märta Ekdahl has typed parts of the manuscript and all tables, Agneta Nordgren has drawn many of the diagrams and maps, Folke Hellström has done the photographic work and Åke Sjödin and Salme Sedman have helped with library work. Nigel Rollison kindly helped me with the linguistic revision.

The editors, Gunnel Sjörs and Erik Sjögren, patiently aided me during the final stages of publication.

Wille and Reet Ländta, Aktse, helped me in many ways and actually made the field-work possible by providing transports and lending me a boat, and by taking responsibility for the readings of the water-level gauges; for this and their warm friendship I am most appreciative. During several summers my brother Dan Waldemarson patiently assisted me in the field.

Nils Malmer, head of the Department of Plant Ecology, Lund University, has provided working facilities for many years.

My husband Sven Jensén, Department of Plant Ecology, Lund, has taken an active part in my work during its various stages.

During the years, I have had many hours of valuable discussions with friends and colleagues at both Institutes, in Uppsala and Lund.

This work has been supported by grants from the National Swedish Environment Protection Board.

To all mentioned and to all others who have in some way taken part in the investigation, I convey my sincerest gratitude.

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Waldemarson Jensén, Eva, 1979, Successions in relationship to lagoon development in the Laitaure delta, North Sweden, Acta Phytogeogr. Suec. 66, Uppsala. 128 pp.

The development of the vegetation from 1904, as interpreted from photographs, to 1974 is shown for 6 delta lagoons which in 1973 had different water regimes. The totally open lagoons had almost as large a water-level amplitude as the passing distributary. Their autumn water-table is low, while the lagoons connected by channels with low-water thresholds of different height had a much lower water-level amplitude and a relatively high autumn water table. The swamp vegetation is disintegrating and the willow vegetation is dying close to these lagoons with high low-water thresholds.

Vegetation types were distinguished along the zonation from a levee crest to the open water of a lagoon, and their relations in a progressive or retrogressive succession are outlined. Vegetation types indicative of retrogressive development are confined to areas near closed lagoons.

The bottom sediments along a transect across a lagoon which had become closed during the period documented by photos revealed drowned swamp vegetation, but also that the zonation of vegetation material in the sediments is possible to relate to the rise in water-level from the times when the lagoon was a bay to Lake Laitaure and an open lagoon with channel connection to a distributary.

The processes and time scale attached to the dying-off of swamp and willow vegetation are exemplified from delta lagoons and discussed.

A succession scheme showing possible pathways for the hydrarch succession in the Laitaure delta is shown.

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1. Introduction

The Laitaure delta, where the present investigation was performed is situated at the eastern border of the Scandinavian mountain range in Lule Lappmark at N 67°10′, E 18°10′ (see Fig. 1), just at the western (upper) border of the prealpine coniferous woodland subzone. Spruce is rarely found in the delta. Birch vegetation covers the higher levels and willow and swamp vegetation dominate in lowlying areas. The Laitaure delta is one of the largest and most rapidly growing lake deltas in Sweden and it is influenced by man only to a very minor degree. Large areas of the delta are occupied by vegetation types indicative of retrogressive successions. There are areas where willow shrubs and birches are dying and where swamp areas disintegrate and become open water areas of lagoons. The areas where retrogressive successions have been found are situated in or adjacent to lagoons with a water regime differing from that of the delta distributaries. It has been necessary to clarify the development of delta lagoons and to investigate the structure of the vegetation in lagoons with different water regimes in order to understand the dynamics of the delta vegetation.

Some authors regard succession to be only progressive (Philips 1935; McCormick 1968), whereas others also accept it to be retrogressive (Clements 1916; Nichols 1923; Gleason 1927; Tansley 1935; Whittaker 1953; Iversen 1964; Bykov 1957 in Alexandrova 1974; Dansereau 1974). Clements used the term retrogressive succession to describe the invasion of a forest by a swamp due to flooding. Iversen (op. cit., p. 59) used retrogressive succession in a restricted sense: "Only successions that are irreversible under the prevailing climatic conditions, and which lead to ecosystems with permanently reduced organic productivity, are regarded as true retrogressive successions." He also distinguished ... "between two main types of retrogressive vegetational development. The first is connected with the leaching of the soil, while the other is caused by a local rise of the ground watertable." Tansley regarded the replacement of a 'higher' by a 'lower' vegetation as a retrogressive succession. McCormick (1968 p. 24) considered succession to be progressive in the sense that "The new vegetation type that develops on an area is more complex than the type it replaces". He judged that greater complexity could arise from an increase in one or more of the following attributes:

1. Diversity
a) of life-forms present
b) of species present
2. Structure
a) Stratification of aerial parts
b) Stratification of subterranean organs
c) Height of 'dominant' plants
d) 'Closing of stand' (per cent of ground covered)
e) Intensification of competition
3. Stability of the vegetation type
a) Resistance to replacement
b) Ability of the component species to complete their life histories, to reproduce, and to maintain the composition of the vegetation type
4. Uniformity of type
a) Intrastand homogeneity
b) Interstand similarity
5. Productivity (as measured by energy stored in organic compounds per unit area per unit time) and biomass (amount of organic material present at some point in time)
6. Modification of site
a) Soil development (degree of change from parent materials), especially humus content
b) Modification of microclimate (humidity, wind, temperature, light, precipitation).

Since progressive successions are considered, in McCormick's terms, as vegetational development towards greater complexity, retrogressive succession, as a consequence, should be considered as a reduction in complexity in most or all of the above-mentioned properties.

Some of these criteria, e.g. diversity (1) and uniformity (4), may be contradictory to each other, and not all of them may really lead to greater "complexity". Stability (3) could by a different definition decrease through succession, as pointed out by Horn (1974 p. 32), who writes: "Disturb early succession and it becomes early succession. Disturb a climax community and it becomes an early successional stage that takes a long time to return to climax." Whittaker (1953), who gives a similar set of criteria, considers increased productivity as the most important property of a progressive succession (but this is not generally valid in, for example, the taiga forest), and a decrease in productivity as most significant for a retrogressive succession.

Fig. 1. The investigated area and the drainage basin of the River Rapaätno. 1. Areas below 800 m; 2. Areas between 800 and 1200 m.; 3. Areas more than 1200 m above M.S.L.; 4. Glaciers; 5. Lakes; 6. Brooks and rivers.

In places, the progressive succession in the Laitaure delta leads to what could be called a temporary climax (cf. Gleason 1927). He wrote that there are no climaxes, only that the changes are just too small to be observed, which is the case in some of the land covered by birch or willow. The retrogressive successions in the Laitaure delta, on the other hand, pass through many stages and can even reach a comparatively stable stage of aquatic vegetation.

The causes of succession are considered to be either autogenic or allogenic (Tansley 1929) or a combination of both. Probably the driving force of plant succession can be determined to be multifactored (McCormick 1968 p. 33). Gill (1973b p. 64), working in the Mackenzie delta, states that allogenic changes of the environment (caused especially by sedimentation and flooding) force the successional direction, but also that autogenic forces slowly increase through the seres until the 'climax' community, at which stage they dominate over allogenic influences. This, however, is only partly true in such an unstable environment as the Laitaure delta.

The driving force for the retrogressive succession in the Laitaure delta is thought to be a negative change in the arithmetic difference in level between the vegetated ground level and the low-water table. This arithmetic decrease, theoretically, could be caused by a lowering of the ground level or a rise in the low-water level or a combination of both. A lowering of the ground affects both high-water and low-water levels relative to the ground level about equally, whereas a rise in water-level due to formation of a threshold in the outlet of a lagoon may be confined to low-water conditions.

The retrogressive succession may lead back to a state already passed in a previous progressive succession; but often species combinations and structures are formed which are not to be found in the progressive succession (deflected succession, see Whittaker 1953).

Cooper (1913) distinguished between hydrarch (beginning wet) and xerarch (beginning dry) primary succession (see also Dansereau 1974). This division is applicable to the successions in the Laitaure delta as well. At the delta front, areas sheltered from bottom-transported sediments develop as a hydrarch succession, but on the subaquatic levees (transverse bars) there is a xerarch development.

Van der Valk & Bliss (1970) claim the succession in slough lakes to be identical with the zonation but this can hardly be applied to the Laitaure delta. Gleason (1927) pointed out that a contact between two associations does not necessarily imply that there has been or ever will be a succession between them. In fact, numerous retrogressive or haphazard successions occur in freshwater and on lake shores due to wave or ice action, sudden highwaters, etc., upsetting regular zonations.

1.1. Aims of the investigation

The aims for this part of the investigation have been:

To clarify the development from an open delta bay with the same large water amplitude as Lake Laitaure itself, or as an adjacent delta distributary, towards a closed lagoon with small water-level fluctuations except on occasions of inundation by extreme high water.

To show the physiognomic and structural change of the vegetation at the closure of lagoons and possibly the abiotic or biotic causes of these changes.

To investigate the further development in closed and nearly closed lagoons as documented on sequences of old and new photographs, and by vegetation and substrate structure.

To show the importance of different water regimes for the vegetational zonation and development.

1.2. Definition and characterization of terms

The following terms are frequently used in this paper; they are defined below (arranged alphabetically):

Bar. "An accumulation of sand or gravel in a river rising to near the surface of the water" (Martvall & Nilsson 1972 p. 2).

Bed-slope (bottomset, foreset or topset). Gilbert's studies in Lake Bonneville (Gilbert 1890) led to the concepts of topset, foreset and bottomset beds (see Fig. 2). It is, however, not possible to apply this terminology to all different kinds of deltas and especially "not to large modern deltas along continental margins" (Morgan 1970b p. 108). Axelsson (1967 p. 24) states: "I mean by 'foreset slopes' and 'foreset beds' only those parts of the frontal slopes and beds of aggradational origin where the dip angles are greater than 10 degrees, and by 'bottomset slopes' and 'bottomset beds' those parts below the foreset slopes where the dip angles are lower than 10 degrees."

Generally the development and characteristics of the foreset and bottomset slopes depend on the depth of the basin into which the delta is built, density-differences between basin water and river water, the characteristics of the water flow and the coarseness of the sediment load.

Compaction. "Compaction, decrease in volume of sediments as a result of compressive stress, usually resulting from continued deposition above them" (American Geological Institute 1957 in Mead 1963). This process is called consolidation in the soil-mechanics literature (Meade 1963).

Consolidation. "Consolidation 'any or all processes whereby loose, soft, or liquid earth materials become firm and coherent' (American Geological Institute 1957 in Mead 1963). This includes cementation as well as compaction" (Meade 1963).

Delta. "A deposit, partly subaerial, built by a river into or against a body of permanent water" (Barrel 1912 p. 381).

The Laitaure delta is classified as a subaquatic–subaerial delta. For further discussion see Axelsson 1967, p. 9–10.

Distributary-channel. In the delta plain two different kinds of streams can be distinguished: the river branches where water flows only in one direction, i.e. from the proximal part of the delta towards the distal part, and the channels developed between the river branches and the lagoons where the stream direction can be reverted. In this paper the former are called distributaries and the latter channels. Some small distributaries in the Laitaure delta are abandoned and exist as lagoons but no main distributaries have yet been abandoned, in contrast to conditions in many other deltas (see Russel 1936; McCloy 1970; Dahlskog et al. 1972).

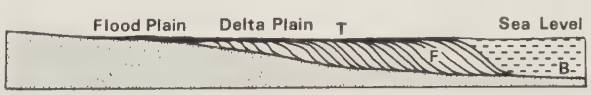


Fig. 2. Schematic section through the sediments of a Gilbert-type delta (from Holmes 1960 in Axelsson 1967). T=topset, F=foreset, B=bottomset beds.

Graded river. "A river which is in equilibrium with regard to erosion and deposition" (Martvall & Nilsson 1972 p. 2).

Grain size: stones >20 mm, gravel 20–2 mm, sand 2–0.2 mm, fine sand 0.2–0.063 mm, silt 0.063–0.002 mm, clay <0.002 mm.

I have used the above terminology for sediment grain size as being easily distinguished in the field (see also Atterberg 1903).

Helicoidal flow. "The spiral flow in the cross-sectional plane of a channel due to centrifugal force" (Martvall & Nilsson 1972 p. 2). The helicoidal flow causes a superelevation of the water surface against the outer, concave bank in a curved channel. The helicoidal flow is responsible for the accumulation of point bars (Allen 1965). Gill (1972a) points out that the 'cross channel velocity component' (Leopold 1962 in Gill 1972a) causes coarse bed load to be swept laterally toward and up the bank of the levee to be deposited.

Interlevee basin = floodbasin or *backswamp.* "Floodbasins are the lowest lying parts of stream floodplains. They are poorly drained flat, relatively featureless areas of little or no relief located adjacent to or between abandoned or active, but slightly higher, meander belt alluvial ridges. Floodbasins act as stilling basins in which suspended fines can settle from overbank flows after the coarser suspended debris has been deposited on levees and crevasse-splays" (Allen 1965 p. 123). Wohlman and Leopold (1957) reached the opinion that over any longer period a stream bed and the local floodplain appear to keep a constant relative elevation.

Mackay (1963 p. 132) reports from the Mackenzie delta that: "Well over 90 per cent of the delta lakes are floodplain lakes (lagoons) which occupy depressions rimmed by the higher land along the channels." This is also true for the lakes (lagoons) in the Laitaure delta.

Levee. "Natural levees are wedge-shaped ridges of sediment bordering stream channels. Their elevation is greatest at or close to the edge of the channel, where they commonly form steep high banks, and from there gently slope away into floodbasins at a distance from the channel. Levees are best developed on the concave banks of streams. On the pointbars of the convex banks they are rarely so well developed as to mantle the accretion topography completely. The construction of levees is largely responsible for the superelevation of alluvial ridges above the general floodplain. Deposition on the levees occurs when a stream overtops its banks ... The coarsest debris is laid down close to the channel and the finer material further down the levee at a greater distance from the stream" (Allen 1965 p. 121).

"The amount of sediment deposited along the backslope of the aggrading levee is in equilibrium with the rate of recession along the bank face so that this type of levee migrates laterally across the floodplain without greatly altering its cross-sectional dimension or form" (Mackay 1963). This is probably also true for the Laitaure delta where the distributaries do not meander but migrate. The break-down of levees has been noticed by Kolb (1962): "When a stream is not in flood, its levees are attacked by atmospheric agencies and in particular are eroded by rainfall" (from Allen 1965 p. 121).

Meander scroll and meander scroll depression. "Elongated, arcuate depressions were observed behind nearly all point bars and adjacent (down-channel) slipoff slopes examined in the Mackenzie delta. The depressions lie between what Davis (1913) originally termed 'scrolls'—long, parallel ridges built within a meander loop by the process of point bar formation" (Gill 1972a p. 46). Allen (1965) also points out that the scroll-shaped ridges and swales are roughly conformable with the curve of the distributary or channel. The meander scroll depressions could hold swamps or lagoons as also pointed out by Mackay (1963) and Melton (1963) (cf. Drury 1956).

Oxbow lake. "An abandoned meander loop formed by cutting off the meander neck" (Marvall & Nilsson 1972 p. 2).

Oxbow lakes do not exist in the Laitaure delta but there are closed distributaries which have become lagoons and which may resemble oxbow lakes.

Point bar. "A point bar is a deposit formed on the inside, or convex side, of a river bend by lateral accretion" (Wohlman & Leopold 1957 p. 91). Thus located to the convex shore of a distributary.

Sod. I have chosen to use sod as defined by Hopkins & Sigafoos (1950 p. 53): "'sod' is a tight, interwoven mat of rhizomes (horisontal underground stems) from which jointed aerial stems (culms) of grasses or grasslike plants arise. The mat forms a nearly uniform vegetation blanket." In the Laitaure delta *Carex aquatilis* is the main sod former.

Swamp. Sjörs (1948) applied the now commonly used term *wetland* to vegetation where the subsoil water was redundant and its level near the surface of the soil. He distinguished "limnogenous wet of soil caused by inundation or permanent influence of water from rivers and lakes" (Sjörs 1948 p. 279) from other causes of high wetness. In the delta all 'wet of soil' is limnogenous.

Tansley (1939 p. 634) applied the term marsh "to soil-vegetation types in which the soil is waterlogged, the summer water-level being close to, or conforming with, but not normally much above, the ground level, and in which the soil has an inorganic basis. Fen is applied to vegetation and ground with a similar water regime but where the ground is composed of peat which shows a more or less alcaline reaction. The term swamp is used for vegetation in connection with open water areas where the water-level in summertime is above ground level. For the outermost parts of the vegetation surrounding an open water area the term reedswamp is used" (see also Warming 1909). It should be noted that in Britain autumn and winter water-levels in swamps are mostly even higher than the water-level in summertime referred to by Tansley, whereas in the Laitaure delta, as everywhere in the boreal zone, winter levels are very low. A special feature of the River Rapaätno is the periods of very high discharge in summer due to the water coming from high alpine snowfields and glaciers.

Large areas of the Laitaure delta plain are covered by vegetation types adapted to more or less permanent waterlogging of the ground.

In the delta different kinds of wetlands can be found depending on the age of the vegetation and the position and level of the area. To use fen throughout would be inaccurate because most of the ground predominantly consists of

minerogenous sediments up to or near the surface, although fens do develop in shallow areas cut off from mineral sedimentation. Marsh could be used for the major part of the ground which is minerogenic, but there is continuous formation of organic sediments too, which in older stands cut off from the river may prevail over minerogenic sedimentation.

The wetlands of the Laitaure delta have a markedly oscillating water-level and are submerged not just once but many times every year. This makes it difficult to distinguish swamp (in Tansley's sense) from marshland and also from fen. Almost all wetlands extend downward from what could be called semi-terrestrial vegetation, i.e. areas covered by healthy willows, down to the open water. The term swamp will be used in this work for the lower part of this zonation. The lowest part of the lagoon zonation, i.e. the part in contact with the water of the lagoons, will be called reedswamp (cf. Warming 1909).

In Scandinavian vegetation science the kind of wetlands occurring in the Laitaure delta have mostly been classified under mire vegetation (e.g. Kalela 1939; Kalliola 1939; Nordhagen 1943; Dahl 1956; Ruuhijärvi 1960). I find it difficult to agree with this classification since there is no formation of what could normally be called peat. Much of the substrate is periodically aerated and the admixture of inorganic particles is large. Other authors e.g. Eurola (1967) use the term meadow for the wetland communities here called swamp. Marsh is used for inland wetlands but when used in marine deltas it is used for the wetlands influenced by the sea, while swamp is used for remaining wetlands.

Topographical height is given in metres above Mean Sea Level (M.S.L.).

Transverse bar. "A bar made up of bed load which extends at right angles to the flood direction. In meandering channels they are generally attached to the convex bank. Transverse bars migrate slowly downstream" (Martvall & Nilsson 1972 p. 2).

1.3. Earlier investigations

The Laitaure delta of the River Rapaätno, one of the tributaries of Lilla Lule River is situated at the eastern border of the Sarek National Park in Lule Lappmark (North Sweden). The river drains a large part of the high mountains and glaciers of Sarek.

The vegetation in the Sarek area was investigated by Tengvall (1920; 1924) with a brief survey of the delta succession (Tengvall 1925). Hamberg (1901; 1910a; 1910b; 1915a; 1915b; 1931) and Hamberg & Jönsson (1933) investigated the geology, geomorphology and climatology of the Sarek mountains. Hamberg also started continuous measurements of climate and water-level variations in the River Rapaätno at Litnok (see Fig. 1). All photographs used in this paper which were taken in 1922 or earlier were taken by Hamberg. Axelsson (1967) studied deltaic morphology and processes in the Laitaure delta. This detailed work has served as a valuable basis for the present study of the vegetation in its role in successional processes.

Only a few of the mountain deltas in Sweden have been investigated as to their vegetation and its development. Dahlskog has studied the vegetation in the Kvikkjokk delta, with brief surveys of other deltas in the vicinity of Kvikkjokk (Dahlskog 1957; 1964; 1966; 1967a; 1970; 1974; 1975). He also investigated the delta formed by two rivers jointly in Lake Ånn (Dahlskog 1967b). Dahlskog et al. 1970, 1972 and 1976 present the results of a multidisciplinary research project. Downstream of Lake Laitaure lake vegetation and the flora and vegetation of now drowned land was investigated in connection with the damming of the valley for Seitevare power plant (Mårtensson 1962; Rune 1965; Granmark 1965). Karlsson (1973) studied the flora and vegetation on the mountain slopes bordering the delta area.

2. Physical survey of the area investigated

2.1. The delta area

The Laitaure delta is a very gently sloping subaquatic-subaerial delta formation (Axelsson 1967) formed by the River Rapaätno as it flows into Lake Laitaure. It is one of the largest and most rapidly growing lake deltas in Sweden (see Fig. 3), and covers about 10 km^2.

2.1.1. Lake Laitaure

The original lake basin extends in a west-easterly direction for 15 km and has a maximum width of 3 km, but is now half filled with delta deposits. The bottom of the original basin consists predominantly of till which in places rises above the lake or delta level, forming islands. The basin is bordered by steep mountains: Mount Skerfe (1179 m above M.S.L.) rises to the north, Mount Tjakkeli (1214 m) to the south and Mount Nammatj (823 m) in the western proximal part (see Fig. 1 and, e.g., Karlsson 1973).

The basin is classified as a deep marginal ice-lake. Ice-lakes of this type were formed around thick more or less coherent dead-ice bodies remaining in large depressions (Lundqvist 1972). The water-level in Lake Laitaure (494.8 m) equals 150 cm at the water-level gauge at the Aktse bridge (see Fig. 1). This water-level gauge has been taken as a basis of all scales showing levels in the delta. The annual amplitude of the water-level in Laitaure amounts to about 1.6 m (Axelsson 1967) which is a moderate figure for Swedish mountain lakes.

2.1.2. The River Rapaätno

The River Rapaätno drains the central Sarek mountains. Above Lake Laitaure it has a catchment area of 684 km^2, of which 80 km^2 is covered by approximately 40 glaciers (see Fig. 1). Thus glaciers constitute 12 % of the drainage area. The water-level in the Rapaätno and in the deltaic distributaries rises and falls very rapidly with changes in precipitation and temperature. This is due to the large extent of glaciers, to the absence of large lakes—only 3 % of the catchment area consisting of lakes—to the steep topography and to the shallow soil cover within the drainage area. The annual range in water discharge is large, although the variation in actual level is surpassed by many lakes and rivers in North Sweden, even unimpounded ones. The annual variation of the water-level in the Rapaätno is normally of the order of 2.7 m at Litnok (Axelsson 1967) (see Fig. 1).

Due to the large extent of glaciers and the absence of upstream sedimentation basins other than the braided river stretch called Rapaselet, there is a large sediment load reaching the delta. The discharge of sediments amounts, on an average, to about 185,000 metric tons per year at the proximal part of the delta. Of this about 25,000 tons/year is bed-load discharge and 160,000 tons per year is suspended load discharge. About 90 % of the suspended sediment which reaches Lake Laitaure is deposited upstream of the outlet section. Most of it is probably deposited at the proximal part of the delta front. The mean annual extreme values are lower than 0.01 ton per day and higher than 20,000 tons per day, respectively (Axelsson 1967). Axelsson (1978 pers. comm.) has roughly estimated the net deposition at the delta plain to 10,000 m^3/year.

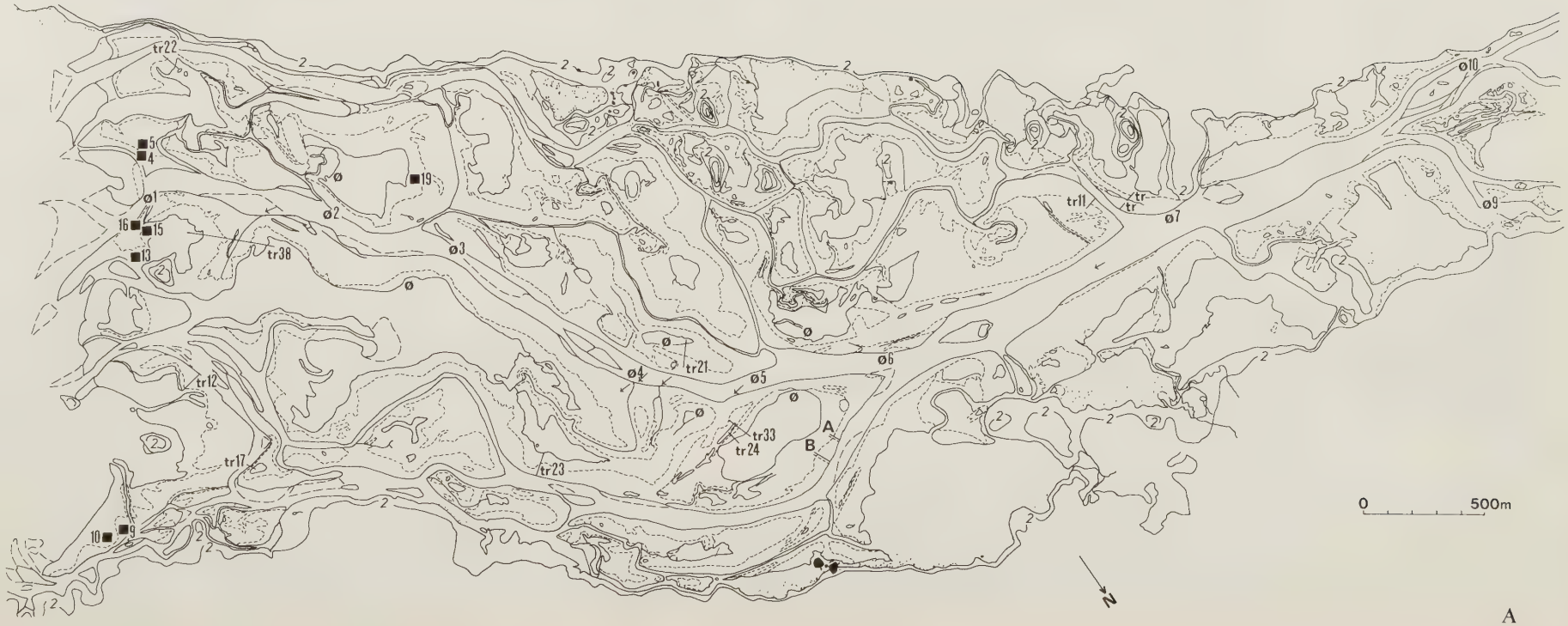
2.1.3. The delta plain

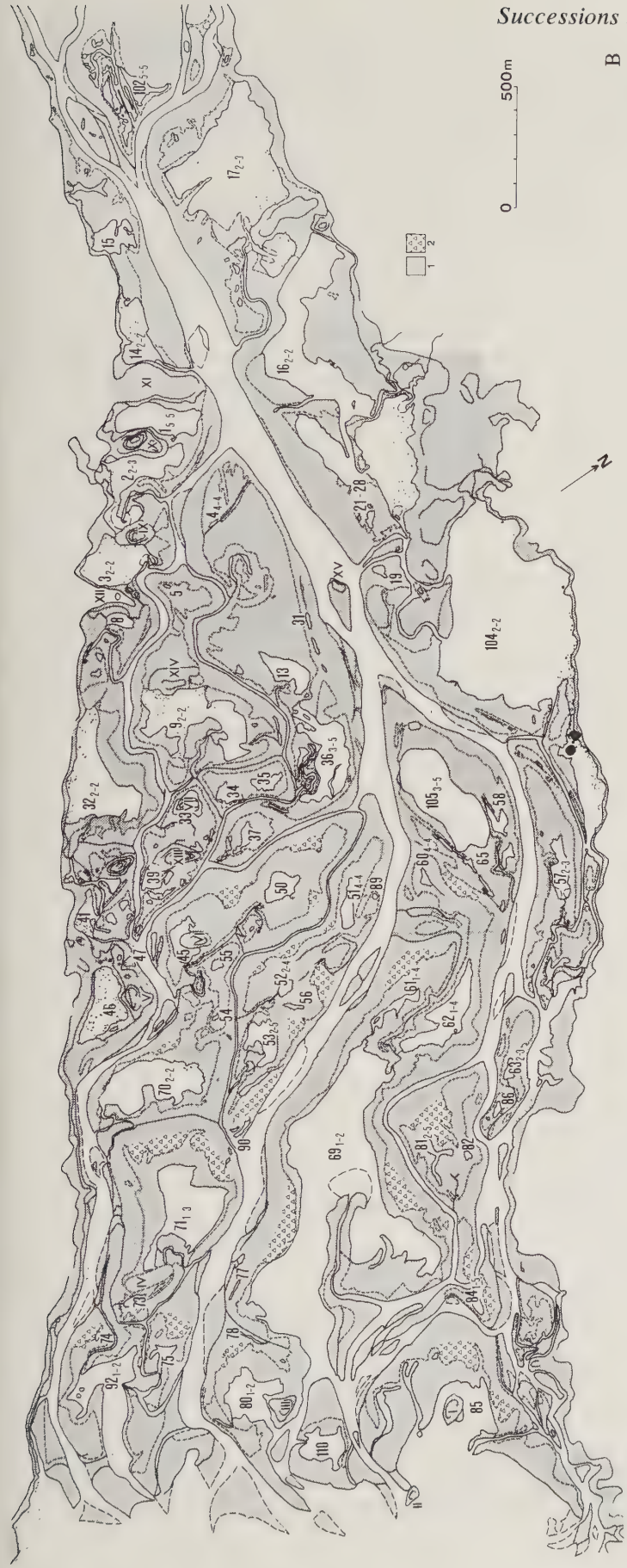
The Laitaure delta floodplain has numerous active distributaries, more or less marked levees and shallow interlevee basins of different types. Abandoned distributaries are few and short, thus having been closed off shortly after bifurcation. Fig. 4 shows the unsuccessful bifurcations, which are mentioned in the lagoon descriptions in Chapter 5. Only one distributary extending in the main stream direction is closed at mean water-level although not at high water (the distributary south of lagoon 51, in Fig. 4). The shape of the delta plain is not lobate but elongate due to the narrow original lake basin. The delta plain is slightly inclined towards the lake and the average longitudinal slope of the levee crests along the active delta distributaries is about 0.2 per mille in the middle part of the delta and about 0.3 per mille in the proximal part (Axelsson 1967).

Lake Laitaure has a maximum depth of 17.8 m and a mean depth of 4.1 m (Axelsson 1967). One may assume a sediment thickness in the delta of the same order of magnitude as the depth of the remaining basin but this is conjectural. Axelsson (pers. comm. 1978) estimates

Fig. 3. The Laitaure delta, compiled by V. Axelsson in 1963 and revised by E. Waldemarson Jensén in 1974. Photogrammetric survey, based on air photos taken on June 18, 1954, by *Rikets allmänna kartverk,* Stockholm.
Generally only the 2 m contour is marked in the surrounding land. Till islands in the delta are properly marked. Short hatched line=the border between swamp and willow or birch covered areas. Long hatched line=limit of sandbars.
1. Open water; 2. Distributaries and channels; 3. Levees with shrubs or trees (*Salix* or *Betula*); 4. Swamps and some dry areas (grass-grown levees and bars); 5. Bars; 6. Boulders; 7. Surrounding land; 8. Mire; 9. Contours in metres above Lake Laitaure (494.3 m above M.S.L.).

Fig. 4. (A and B). The Laitaure delta, compiled by V. Axelsson in 1963 and revised by E. Waldemarson Jensén 1974. Photogrammetric survey, based on air photos taken on June 18, 1954, by *Rikets allmänna kartverk*, Stockholm. Map of names and numbers used in this paper. The lagoons are numbered with Arabic numerals, the indices show the classification in drainage system in 1904 (first index) and in 1974 (second index) (see Table 6). Till islands are numbered with Roman numerals. The water-level gauges in the Kuoutätno and in the intensively studied lagoons are shown (Ø). Contour-levels in metres are drawn. The area where the water-level in the ground was measured is indicated (hatched lines A and B). The location of belt-transects (straight lines, tr.) and plots (rectangles) is drawn. The unsuccessful bifurcations of the Kuoutätno from the bifurcation of the Nuourtätno to Lake Laitaure are indicated (arrows).—(B) 1. Land; 2. Areas where the willow zone is comparatively broad, probably as a consequence of the distribution of water and sediment at bankfull stage and also of the differences in height of the levees surrounding an interlevee basin.

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the mean thickness to be less than 5 metres and the maximum value to be more than 20 metres. These estimates are, however, based on few and not very reliable measurements. In the active parts of the Laitaure delta there is probably a mean aggradation of 1–2 mm per year caused by the growth of the delta. The absolute and relative differences in levels in the Laitaure delta are influenced both by compaction, unequal land up-lift and aggradation. Compaction occurs especially when the sediments are under-consolidated, which is the case over large areas of the Laitaure delta (pers. comm. Axelsson 1978).

The sediments transported to the delta are coarse with a very small percentage of clay. The maximum (by weight) is in the fine sand-coarse silt fractions. About 8 % (by weight) is gravel and sand (coarser than 0.2 mm), and only about 2 % is clay (finer than 0.002 mm according to Axelsson 1967). The sediments originate mainly from mechanical weathering of crystalline rocks (see section 2.2). Boulder bars are only found in the extreme proximal part of the delta and their vegetation is not treated in this paper. Single boulders, probably ice-transported, can be found in the middle part of the delta. Gravel occurs also at the delta front, although sparsely. The predominant particle size is fine sand (0.06–0.2 mm). Table 1 shows the particle size distribution in different deltaic deposition sites and at different depths in lagoon 105 (see Fig. 4). The smallest particles are transported as suspended load and mainly deposited in Lake Laitaure (sample 9), a deposit which underlies the other deltaic deposits where they are deep. Such bottom-set beds of a delta are usually built up of sediments deposited from suspended load in front of the actual delta front (sample 7).

"For formation of foreset slopes bed load transportation is necessary" (Axelsson 1967). This refers to transportation along the bottom of distributaries. Sediments with a mean particle diametre of about 0.18 mm (fine to medium sands) are the best sorted ones and are often characteristic of beaches, river-mouth bars and deltaic foreset slopes. Usually (i.e. on occasions with strong discharge when the largest amounts of particles are transported) particles smaller than 0.18 mm are transported as suspended load while larger particles, depending on current velocity, may be transported both as suspended and as bed-load (Axelsson 1967 p. 25). The grain-size distribution of the foreset slope at the Laitaure delta is shown in sample 4.

The coarsest material is found in transverse bars and point-bars (samples 2 and 3) while levee deposits (sample 6) are less sorted and often stratified. Axelsson (1967) also points out that the grain size of suspended sediments deposited from flood waters decreases with increasing distance from the active distributary, as illustrated by samples 8 and 6, which were collected, after a high water, in the same interlevee basin. Mostly only suspended load is deposited inside an interlevee basin. A lagoon with a channel connection to a distributary is reached by turbid water with every rise in water-level while a closed lagoon only receives sediment at flood.

Samples 10–15 show the grain size distribution in lagoon 105. The material in sample 12 at a depth of 0.5 m below the lagoon bottom was probably deposited in a shallow interdistributary bay while that of samples 10 and 11 was deposited in more sheltered environments and also has a higher organic content. The grain-size distribution in samples 13–15 corresponds to that of

Table 1. The particle size (in mm) distribution in % at different deposition sites at the Laitaure delta (calculated from Axelsson 1967).

Sample	9	8	7	6	5	4	3	2	10	11	12	13	14	15
Depth below bottom (m)									0.1	0.3	0.5	1.0	2.0	3.0
clay <0.002	7	3.5	0.2	.	.	.	.	.	3.6	0.19	0.1	0.1	0.1	0.4
silt 0.002-0.006	13	4.5	0.8	.	.	.	.	.	5	0.5	0.1	0.4	0.7	1.6
silt 0.006-0.02	50	19	12	2	.	.	.	.	18	3	1.6	5.5	11.3	17
silt 0.02-0.06	29	55	52	18	.	.	.	.	59	17	17.4	42	60	60
fine sand 0.06-0.2	.	17.5	29.2	77	82	60	43	8	9	70	69	49	27.5	20.8
sand 2-0.6	.	.	.	2.8	17	39	54	60	.	.	.	.	.	.
sand 0.6-2	.	.	.	.	.	.	2.8	36	.	.	.	.	.	.
gravel 2-6	.	.	.	.	.	.	.	3.6	.	.	.	.	.	.

Deposition sites: 9: Lake Laitaure at max. depth; 8: interlevee basin (lagoon 1); 7: bottomset slope (water depth 2.5 m); 6: levee crest (close to lagoon 1); 5: bar; 4: foreset slope; 3: point bar; 2: transverse bar; 10–15: lagoon 105.

sediments deposited in Lake Laitaure in front of the present distributary mouths (Axelsson 1967). Deposition of sediments in closed interlevee basins thus occurs but is small compared to levee deposition as pointed out by Axelsson (1967), for example in the basin 1 mm and at the levee 2 cm on one occasion.

2.1.4. The delta front

The Laitaure delta is extending into Lake Laitaure by 5 to 7 metres per year (Axelsson 1967). However, the delta front has not yet reached the deepest parts of the remaining basin and thus the speed may be reduced in the future.

The frequency of flooding and the rate of extension into Lake Laitaure might also be reduced compared to the upstream part of the delta since today the basin at the position of the delta front is broader than ever before.

Almost all new land built up at the delta is to be found at the front. Newly formed bars in the distributaries contribute with a comparatively small area. I have studied the pioneer successions, and large areas of the delta front are covered by vegetation types dominated by *Deschampsia caespitosa, Eriophorum scheuchzeri, Carex aquatilis* or *Calamagrostis neglecta*. Comparatively large areas are also covered by vast fields of low (0.5 m) willows. The topography and land structures formed at the delta front persist and become exaggerated with time.

2.2. Geology

"The mountains northwest of Lake Laitaure belong to the eastern part of the Caledonian mountain range and consist mainly of overthrust rock-masses which during the Caledonian diastropism were transported from the Geosyncline area towards southeast" (Axelsson 1967 p. 56). The rocks in the Sarek area belong mainly to two different nappes namely the Amphibolite Nappe and the Syenite Nappe. The Amphibolite Nappe consists mainly of amphibolite, a highly transformed crystalline rock dominated by basic plagioclase. Quartzite and garnet-mica schists also characterize the Amphibolite Nappe. The Syenite Nappe consists of basement rocks, mainly schistose syenite and granite (see Hamberg 1910a and Axelsson 1967, from where further and more detailed information can be obtained). A narrow zone of lime-rich Cambro-Silurian sedimentary rocks is exposed in the mountains surrounding the delta (see Karlsson 1973). Sandstone and shales can be found in the area but crystalline rocks dominate.

During the final phase of the last glaciation the Sarek region was a centre of marked glacial activity (Hoppe & Liljeqvist 1956; Hoppe 1960) and the loose deposits at lower levels predominantly consist of till, often sandy and often rich in boulders (Axelsson 1967).

The general uplift of the land with a maximum of nearly 10 mm per year in the Bothnian region (Atlas över Sverige 19–20), is calculated to be about 6.3 mm per year, on an average, in the delta area (Topographical map Tjåmotis 27 I, height system 1900, scale 1:100,000, 1970). Lake Laitaure is situated in the northwestern corner of map 27 I. The topographical map Stora Sjöfallet 28 I (1968), which covers the delta area, does not give any values for the uplift. At the Norwegian border, approx. 70 km west of the delta, the average uplift amounts to 4.7 mm per year (Topographical map Sulitelma 27 G). The skewness of the uplift thus would be of the order of 2.3 mm per km and century, thus giving, for the lake and the delta together, about 35 mm per century. This is in itself probably too little to influence modern time successions on the delta to a recognizable extent, but may add to the effect of unequal sedimentation and threshold formation in channels, as discussed in following chapters.

2.3. Climate

Continuous meteorological observations relevant to the climate near the delta were started in 1915 at Litnok (505 m), 3 km to the W of the proximal end of the delta (see Fig. 1). These measurements, however, have only been partly worked out. At Aktse (550 m, see Fig. 1) measurements of precipitation and depth of snow cover were started in 1937, and temperature measurements according to the rules of the Swedish Meteorological and Hydrological Institute (SMHI) began in 1957.

The mean annual temperature as calculated for 1901–1930 was −1°C at Aktse (Atlas över Sverige 32). Actual measurements for 1957–1961 also gave −1°C (Axelsson 1967) while in 1967–1972 it was −1.9°C (Karlsson 1973). The monthly mean temperature at Aktse is shown in Fig. 5. January is usually the coldest month and July the warmest. The annual mean temperature on the delta might be lower than at Aktse, since nightly inversions are probably even more frequent on the bottom of the mountain valley, Aktse being situated slightly upslope from the lake.

Permafrost probably does not prevail anywhere in

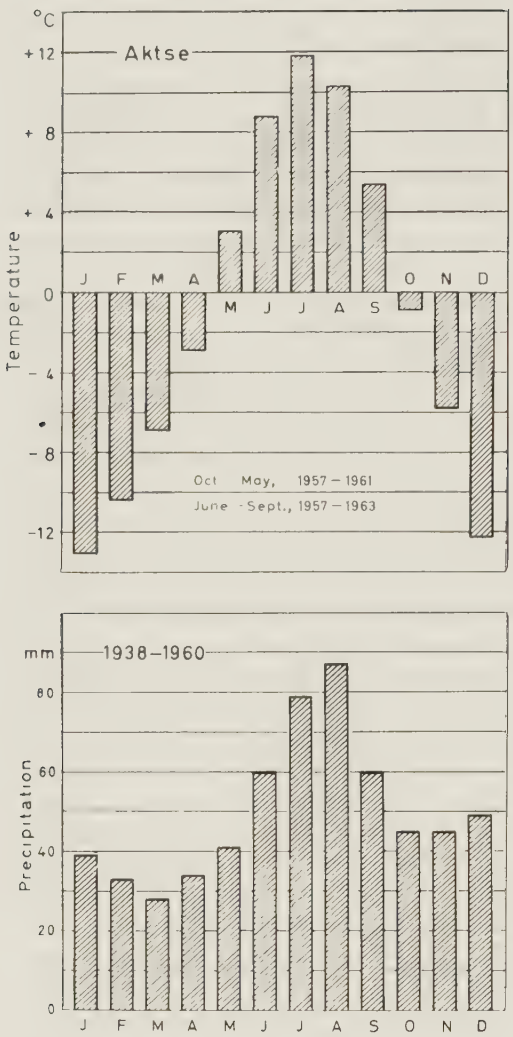


Fig. 5. Monthly mean temperature and monthly mean precipitation at Aktse (from Axelsson 1967).

the delta. Permafrost is rare in Sweden except in the extreme northern part at altitudes above 500 m and with a mean annual air temperature below −3°C and with a low precipitation (<100 mm) in winter time (Ångström 1958); see also Åhman (1977). Scattered discontinuous and very local permafrost is found in the so-called palsas even south of the delta, but these peat-mounds do not occur in the delta nor in its vicinity. Hamberg (1904) reports the soil temperature down to 4 m, the top 1.5 m being frozen in April 1902. His measurements in March 1904 showed the same results. Dahlskog et al. (1972) reported frozen ground 60–70 cm below the ground level when the ground surface started to freeze; although this was in an exceptionally cold year (1971).

The vegetation period, defined by Swedish climatologists as the part of the year with a daily temperature above +3°C, amounts to 140 days (Atlas över Sverige 28) beginning in late May and ending in early October. However, the true growth season is much shorter, due to late snow melting and severe frosts in early autumn.

The mean annual precipitation at Aktse was calculated for 1901–1930 as 600 mm (Atlas över Sverige 32), and for 1938–1960 it was measured as 599 mm (according to data published by SMHI, 1939–1962). The monthly mean precipitation at Aktse is shown in Fig. 5, August being the wettest month. About 40 % of the annual precipitation falls during the winter period (October–March), which would imply that nearly half of the precipitation is snow. For the catchment area upstream, the snow percentage is likely to be much higher. The duration of a continuous snow cover on the delta is roughly 7 months, though snow patches have been seen in mid June.

The Martonne index of humidity in the area during the vegetation period is 40 (Atlas över Sverige 26). Determination of the annual evapo-transpiration according to Tamm (1959), would give a precipitation surplus of 400 mm for the delta itself. But as he explicitly states it is not really applicable to mountain regions.

Lake Laitaure is generally covered by ice from late October to early June (pers. comm., W. & R. Ländta), the delta lagoons and the smaller distributaries usually being covered a couple of weeks longer. In early April 1973 the bottom sediments of six delta lagoons were investigated. All except one were frozen to the bottom, the ice being between 80 and 100 cm thick. Probably all delta lagoons are frozen to the bottom, deep pools excepted, although some lagoons are empty in the autumn and winter.

The water temperature in the delta distributaries is between 7 and 10°C, possibly up to 14°C in summertime. On warm sunny days the surface temperature in the lagoons may rise from 15°C in the morning to 23°C in the afternoon.

2.4. Hydrology

"In the proximal part of the delta the annual variation in river stage is normally of the order of 2–2.5 m" (Axelsson 1967 p. 68). "The younger and lower levees are flooded more frequently and during longer periods than the older and higher levees. The higher levee crests are topped by flood-water only two out of three years on the average ... The duration of water stages higher than the highest levee crests is very short, and usually less than one day" (Axelsson 1967 p. 69). Even though the flood does not overtop the highest levee

crests every year there are always some of the levees bordering a basin low enough to permit high water in the distributaries to reach all lagoons, with possibly a few exceptions. Thus the whole delta, at least up to the swamp and lower willow zones, is reached by sediment-loaded water every year, although in different amounts.

2.4.1. Water-level variation in 1973

The water-level variation has been measured during summer periods in 1972 and 1973 in the distributary Kuoutätno as well as in the lagoons and the results from 1973 are compared with a longer period measured in Seitevare power plant in Tjaktajaure reservoir.

The water-level variation in the delta distributaries is around 2.5 m and the rise and fall of the water-level is faster than in Lake Laitaure. Therefore the water-level variation was measured in the delta itself. The two main aims were to determine the level of the different vegetation types in relation to the duration of different water-levels and to compare the water-level fluctuations in the lagoons with those in the delta distributaries.

The slope of the water-level in the distributaries varies mainly depending on increasing or decreasing discharge in the River Rapaätno and on high or low water-level in Lake Laitaure. The influence of Lake Laitaure reaches further into the delta at high water in the lake than at low water, since the sloping water-levels of the delta distributaries meet a more horizontal water-level induced by the high water even upstream of the actual delta front.

Methods

Nine water-level gauges were placed in the main distributary, the Kuoutätno. This is the only distributary where navigation by motorboat is possible at mean water-level. Since recording gauges could not be used it was the only one where regular readings could be made. The gauges consisted of a scale on a wooden panel fixed into the bottom of the distributary. The gauges were levelled to fixpoints in the delta-level chain. They were levelled regularly to detect possible disturbances. For position of the gauges see Fig. 4. Regular readings were performed in 1973 between June 14 and July 24 and between August 29 and September

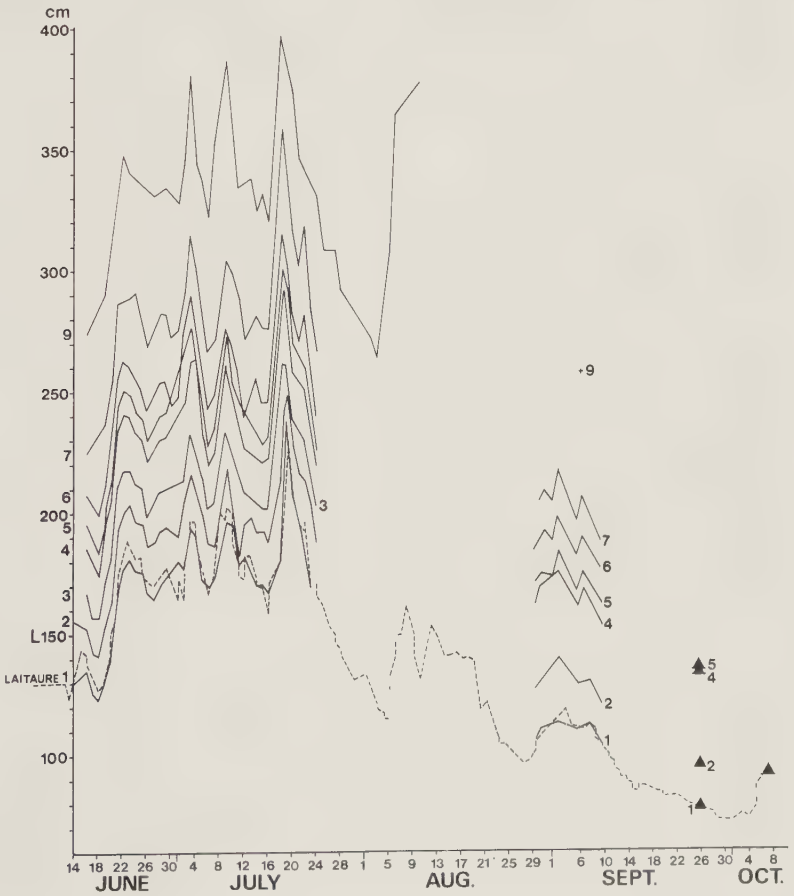


Fig. 6. Water-level variation in the distributary Kuoutätno in 1973 measured at 8 points, water-level gauges 1–7 and 9 (for position see Fig. 4) compared with the gauge at the Aktse bridge (hatched line). 150 cm on the abscissa is equivalent to 494.8 m above M.S.L. To the right the water-level for some of the gauges in the lagoons is marked (triangle) at freeze-up, September 24, 1973. The water-level at freeze-up in Lake Laitaure 8 October 1973 is marked. The level is influenced by formation of ice in the lake.

9. Only water-level gauge No. 9 and the one in Lake Laitaure were read in August. Nos. 1, 2, 4, 5 and 6 were also read on September 24 at the freeze-up of the lagoons.

Straight lines have been drawn between the water-level values for each day, even when days are missing, and despite the fact that during a day water-levels as much as 2 dm lower than the ones plotted might have occurred. The water-level in the delta shows a marked daily variation but this has not been a primary interest in the present investigation. The discharge in the river follows the daily temperature fluctuations as well as day-to-day temperature and precipitation differences (Axelsson 1967). Often, many readings were performed on the same day but in the diagram the highest values for either a.m. or p.m. are plotted. However, most of the values were recorded between 8 and 10 a.m. In Lake Laitaure the gauge was read at 0730 and 1700 and both values are plotted.

Results

Figure 6 shows the water-level at 8 points in the distributary Kuoutätno and one in Lake Laitaure. As the change of the water-level is rapid and the minimum time lapse between readings of No. 1 and No. 9 was one hour, comparisons of single sets of readings cannot strictly be made except at fairly stable low-water stages.

Discussion

At high water the differences between the water-level values at the gauges are larger than at low water but nevertheless the values correspond quite well. The water-levels in Lake Laitaure are not directly related to the water-levels upstream of the lake. After a long period of high water the correspondance of the rising and falling is better than after a low-water period, when the level in Laitaure does not rise as fast and as much as the level in the distributaries. Still, the values from Lake Laitaure can be used to extrapolate the duration of different water-levels in the distributaries and to estimate the general water-level variation during those parts of the vegetation period when no measurements were made in the delta.

2.4.2. The water-level variation in 1973 compared with data from 1910–1973

As the water-level in the delta distributaries and especially the frequencies of extreme high waters are important for the vegetation and for the interpretation of the performed water-level measurements in the lagoons it is of interest to compare the water regime in 1973 with those occurring over a longer period of years, the emphasis being placed on the regime during the vegetation period, May to September.

Methods

The water-levels in Lake Laitaure at Aktse were measured by W. Ländta during different periods prior to 1970. Since 1970 he also read visually the water-levels from break-up to freeze-up once or twice a day.

In the former River Blackälven, now Tjaktjajaure reservoir and Seitevare power plant (see Fig. 1), water-levels have been measured since 1910 with a break during 1920 to 1923. The water-level measurements have been transformed to water discharge. Following completion of the reservoir in 1966 the water-level in the reservoir is being measured and calculations are made of what could be called "normal water discharge". Monthly mean values for the period 1910–1950 have been published by Melin 1955 and the values from 1950 on are available from the Swedish Power Administration (*Statens Vattenfallsverk*). The water collected in the reservoir comes only partly from Sarek National Park. Apart from the River Rapaätno one other river empties into the reservoir, viz. the Sitoätno which flows in from the north-east.

Results

The frequency of monthly mean water discharge values at Seitevare during the period 1910–1973, a total of 61 years, is shown in Fig. 7. The diagram reveals that out of 61 years only 5 years have had such a high or higher mean water discharge in July as in 1973. A similar condition applies to June 1973 whereas in May, August and September the water discharge in 1973 was comparatively low. The mean for the monthly mean water discharge during 5 time periods from 1910–1973 is shown in Fig. 8.

Discussion

The measured water-levels in July 1973 thus were comparably high, but the water-levels in the lagoons at freeze-up were probably independent of the earlier high-water level since in August and September the discharge was comparatively low, which gave ample time for lowering of the levels in the lagoons.

As the means for the different months (see Fig. 8) are not significantly separated it can be assumed that there has not been any drastic change in the water discharge from 1910–1973. The trend is not towards a larger discharge but possibly towards a slight decrease in the summer.

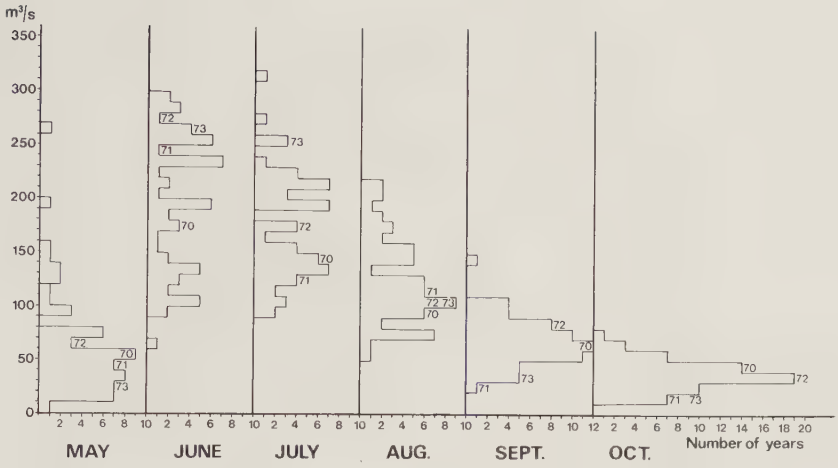


Fig. 7. The frequency of the monthly mean water discharge in m³/s during the vegetation period measured at Seitevare from 1910–1974 (except 1921–1923). The investigation years are marked.

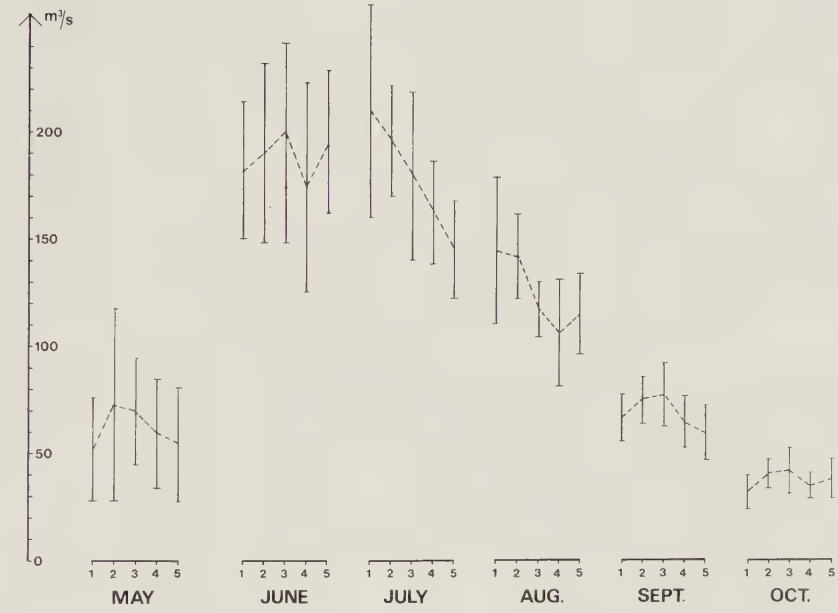


Fig. 8. Mean value for the monthly mean water discharge in m³/s during 5 different periods from May to October. 95 % confidence interval is indicated. Measured at Blackälven—Seitevare (see Fig. 1).
1. 1910–1923; 2. 1924–1935; 3. 1936–1947; 4. 1948–1959; 5. 1960–1973.

2.5. Cultural influences

The Rapa Valley lies in the district of the Sirkas Lapp Village and has been used for summer pasture of reindeer. However, since 1938 only occasional reindeer are to be found in the Lower Rapa Valley (pers. comm. W. Ländta). At the foot of Mount Skerfe, once regarded by the Lapps as a holy mountain, lies the lagoon Saiva (104) where the Lapps had a place of sacrifice. In the vicinity of the lagoon a Lapp fisherman's wife had her settlement in the early nineteenth century. The settlement, Aktse, was registered in 1829 (Hultblad 1968) but had served as winter fishing place for a Lapp since 1763. Around 1864 there were 4 cows, 6 goats and 15 sheep kept at Aktse (Andersson 1865) and the delta was probably harvested for hay as early as this time. Andersson (1865) also remarks that there were extensive pastures there although not so good as those at Kvikkjokk. In 1884 the areas used for harvesting by the inhabitants of Aktse were mapped and classified according to the vegetation and its value as pastures and for hay-making (see Fig. 9). This classification was also the basis for the taxes and gained legal force in 1909 (Friedlieb 1884).

By comparing the land survey map and the old photos I found it likely that the vegetation being harvested was primarily of two different kinds, viz. (1) the sedge and horse-tail *(Carex aquatilis, C. rostrata* and *Equisetum fluviatile)* vegetation around the lagoons, and (2) the pioneer vegetation on relatively young bars possibly dominated by *Calamagrostis neglecta*. The latter species is, according to Frödin (1952), a valuable forage species. Small sedges and mixtures with horse-tail were regarded best (pers.

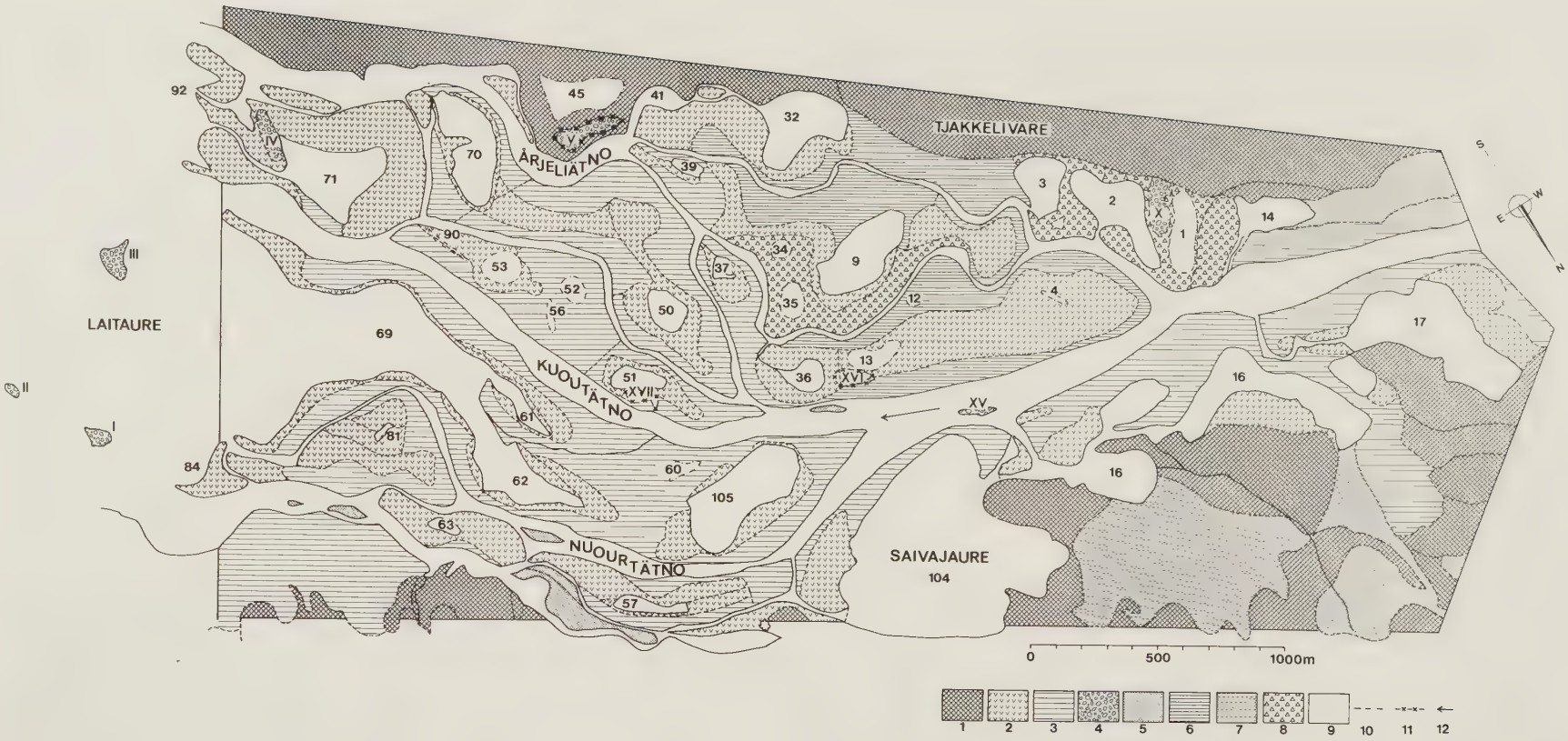


Fig. 9. A delineation map of the land use recognized and drawn by E. A. Friedlieb in 1884. The present vegetation classification has been somewhat simplified. As many boundaries are wrong and many lagoons and till islands are missing on the original map, I have added some of these objects. I have numbered the lagoons with Arabic numerals and the till islands with Roman numerals.

The original classification is given, translated from Swedish: 1. Stony sand esker, useless; mountain ground, mountain birch; Tjakkeli mountain. 2. Fen meadow, sedges; sedge harvest; meadow, sedge harvest. 3. Thicket land, useless; thicket land; thicket land, willow shrubs. 4 and 5. Island, useless. 4. Till island. 5. Sand bars. 6. Shore (river bank), useless; thicket land, river bank, useless. 7. Mire, useless; tree covered mire, useless. 8. Useless ground, mountain spruce (no mountain spruce have grown in the delta during the last 200 years; pers. comm. W. Ländta); forest land, mountain spruce. 9. Open water. 10. Lagoons not mapped originally. 11. Former till islands not mapped originally. 12. Direction of current. Hatched lines represent the originally classified areas.

comm. W. Ländta). Cows, sheep, goats and horses were kept at Aktse. The sheep grazed on the till islands during the summer and birch foliage was regularly cut in July and used as forage (pers. comm. W. Ländta). After around 1940 only one horse was kept. At the same time the harvesting on the delta ceased.

The human influence on the delta seems to have been nearly restricted to harvesting and possibly dredging of some lagoon channels, e.g. that of lagoon 105 (pers. comm. W. Ländta), but no other kinds of water-level manipulations were performed. In many other wetlands the water-level has been changed in order to favour one or another species, to remove unfavourable species groups, e.g. *Sphagnum* and shrubs, or to fertilize (Frödin 1952). In these other wetlands the water-level was raised in the autumn by damming, producing an open water surface and thus ice in the normally icefree shrub zone. At break-up shrubs and mosses which were frozen into the ice were carried away with the ice, leaving the sedges (Campbell 1948; Frödin 1952). Such manipulations, however, are out of the question in the Laitaure delta, since the lake itself has not been dammed. *Sphagnum* spp. are not a common or dominant constituent in the swamp vegetation in the Laitaure delta, probably due to the frequent flooding and silting (cf. Drury 1956).

In the Kvikkjokk delta some ploughing and much harvesting occurred, and several ditches were cut through the levees in order to increase water fluctuations in the interlevee areas, thus improving sedge growth (Dahlskog 1957; Damberg 1977). Dahlskog points out that no other water-level manipulations than dredging of a few meadows have been performed.

Dredging of the channels in the Laitaure delta could have had three purposes: (1) to lower the water-level at harvesting time, and (2) to create new land for the sedges or to maintain swamp vegetation or (3) to create possibilities for bringing a boat into the lagoons. Harvesting was carried out in July (pers. comm. W. Ländta) as also in Kvikkjokk (Dahlskog 1957). Dahlskog points out that the delta could not be harvested until the flood had receded (Dahlskog 1957). In lagoons with a high low-water threshold, e.g. lagoon 105 (see section 5.2.6.1) the water-level is high throughout the autumn, which probably restricted the possibilities of summer harvesting. Frödin (1952) reports of harvesting from a boat. Although this was hardly possible in the delta as the boat had to be dragged over the levees into the lagoons, this method has on occasions been attempted. Harvesting was done from the ice in some years (pers. comm. W. Ländta), which also was noted by Frödin (1952), and then especially for *Equisetum fluviatile*. There are a few reports that one did not harvest standing in water, but on the other hand Frödin also mentioned that *Carex rostrata* and *C. aquatilis* were highly valued and therefore sometimes harvested in metre-deep water. The forage value of the dominant species *Carex aquatilis, Equisetum fluviatile* and *Carex rostrata* is comparatively high (if the harvest is not too late), *Carex aquatilis* being the most valuable (Frödin 1952).

For the reasons mentioned and since the larger part of the winter forage had to be harvested in the delta, it is possible that some of the lagoon channels have been dredged. In the lagoons which now have a high low-water threshold the extension of the swamp vegetation diminishes (see section 5.2.4). This does not preclude the possibility that dredging was performed in the channels of those lagoons where the swamp areas were at that time large and a threshold was under formation.

3. Lagoon formation

Mackay (1963) distinguishes 5 lagoon types in the Mackenzie delta primarily on a genetic basis. He first divides them into (1) abandoned channel lakes, (2) arcuate (pointbar) lakes, and (3) flood-plain lakes. In the Mackenzie delta over 90 % of the delta lakes are flood-plain lakes. These were again sub-divisible into three main types namely "newly formed island lakes occurring on the seaward alluvial flats; lakes with closure; and open lakes with channel flow" (Mackay 1963 p. 132).

In the very different Laitaure delta flood-plain lagoons were most frequently formed as interlevee basins embayed at the delta front. However the importance of closed distributaries and meander scroll depressions should not be neglected. As the delta front gradually rises above mean water-level in Lake Laitaure, interlevee basins are formed when distributaries bifurcate. Very often either the bifurcation of the distributary or the embayments of the interlevee basin are influenced by islands or peninsulas of till. In the Laitaure delta the number of converging and diverging distributaries is very large, due to the elongated shape of the delta, and in consequence also the number of lagoons is large (Axelsson 1967).

3.1. Bar building, distributary splitting and channel formation

The following description is directly taken from the work by Axelsson. See also Fig. 10, which is partly modified from Axelsson (1967).

"The formation of distributaries and interlevee basins at the distal part of the delta (the delta front), may be briefly described as follows: At the mouths of the distributaries where the flanking levees are low and poorly developed, the river water spreads laterally and mixes more or less with the water of the adjoining basin. The marginal diffusion and deceleration of the expanding flow results in a deposition of bed load and suspended load that often creates a broad concentric distributary-mouth bar (A_1, A_2). As the bars grow in size they will deflect and split the flow and often cause the channels to bifurcate (B_1, B_2, B_3, B_4). As the new channels extend basinward they may bifurcate again and sometimes distributaries that converge upon each other may merge. If the splitting, extension and merging or re-joining of distributaries is followed by the development of new, more or less divergent and convergent levee systems, interlevee basins (C_1, C_2, C_3) may be embayed and later cut off from the frontal lake or sea basin. During high discharges minor overflow channels may be formed, widened and deepened at the outside of bends, and especially at the distal part of the distributaries where the levees are low and poorly developed and the vegetation is sparse. The majority of these channels are short-lived, some may evolve to larger distributaries while some may come to function as smaller channel connections (D_1, D_2) with the interlevee basins. The passage at the distal part of embayed areas often remains open for many years after it has been cut off from direct connection with the frontal lake or sea basin. Sometimes this passage (E) develops into a channel that carries turbid river water into the interlevee basin during rising river stages and

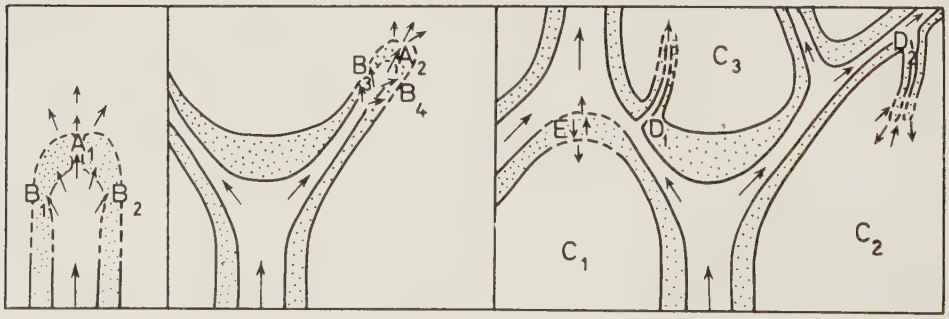


Fig. 10. Schematic formation of distributaries and interlevee basins. For explanation see section 3.1. (from Axelsson 1967).

clearer basin water out to the river channel during falling river stages."

Dahlskog et al. (1972 p. 29) gives a good description of the development of an assymetric cleavage bar.

3.2. Lagoon establishment

The young interlevee basin can be regarded as a bay of Lake Laitaure having the same water-level fluctuations and amplitude. After the opening has become narrower and finally taken the form of a deepened inflow, a

Fig. 11. Lagoon 110 at the delta front in 1963 above and in 1974. The lagoon was initiated between 1954 and 1962. The inflow is still situated at the original position. See also Figs. 16 and 17.
Photo 1963, Ragnar Johansson.

lagoon is formed. The time lapse from bay to lagoon formation depends on the original depth of the basin, on the inclination of the foreset bed, on fluvial processes along the delta front shore, the size position of the bay and on the final direction of the opening between the lagoon and the delta distributary. Usually there is only one open connection to a lagoon, situated at the original position of its formation (see Fig. 11), and serving both as inflow at rising waters, and as outlet when the river and lake are sinking. Smaller channel connections formed from crevasses in low levees will normally become closed by accumulation as they are often situated in the western (i.e. upstream) part of an interlevee basin. Channels with a smaller angle than 90 degrees to the direction of the streaming water are hardly ever kept open for any longer period of time. There is not any lagoon in the delta where the inflow is directed towards the direction of the river current. The persistent inflows are situated in the downstream part of an interlevee basin mostly either on the northern or southern side of it.

The levees around a lagoon are built up constantly by deposition of water-transported sediments at high-waters. The original transverse cleavage bar usually grows fast but since the two sides are nearly always unequal one of the two distributaries rapidly becomes leading and the other one is closed (see Fig. 12). In consequence there will be large differences in the height of the levees surrounding an interlevee basin.

It should be pointed out that delta lagoons are never symmetrical. The western (upstream) levee border is older and the water in that part deeper. The height of the levees to the north, south and east depends on the distributary activity along them, but usually the levees are broad and comparatively low in the eastern and western parts of a basin and high and narrow with a more marked levee ridge along the southern and northern sides. The amount of sediments deposited and the particle size distribution is also different in different parts of a lagoon.

3.3. Closure of lagoon channels and development of low-water thresholds

As mentioned above, connections develop between the lagoons and the delta distributaries. Usually only one channel persists and therefore works as both inflow and outflow to the lagoon.

3.3.1. Channel-lagoon junction

The channels passing into the lagoons very often build up miniature deltas in the lagoons, 'reversed deltas' according to Gill (1974 p. 63). The formation of a minia-

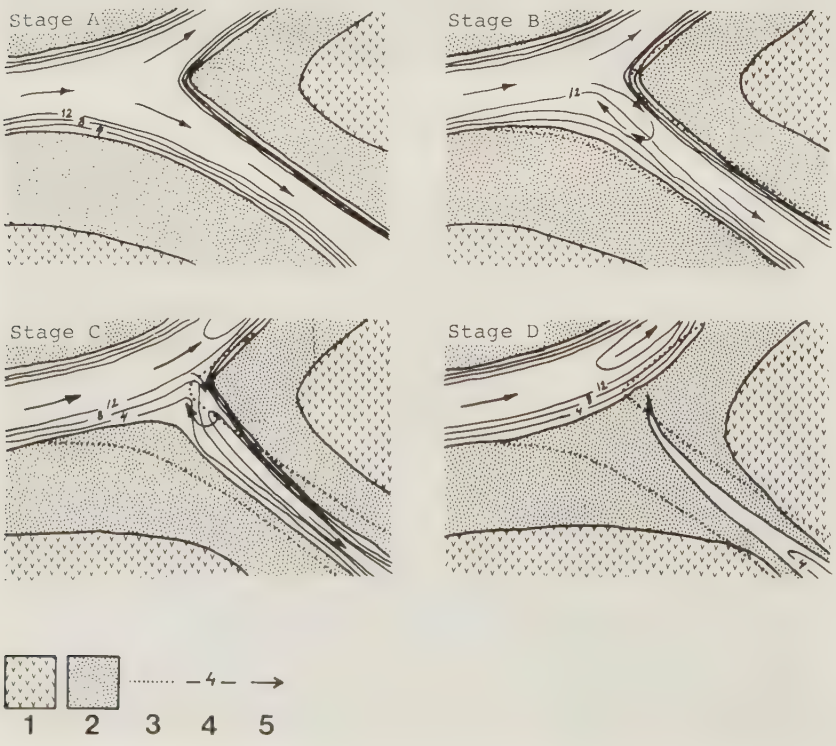


Fig. 12. Schematic development of distributary closing in a time sequence from A to D (from Welder 1959 in Axelsson 1967).

1. Swamp; 2. Levee; 3. Stage A, marked in B–D; 4. Isobaths, dm; 5. Current direction.

ture delta follows the same principles as the formation of a large freshwater delta with the exception that water flows in two directions. However, only the ingoing water carries a sediment load, and moreover the outgoing current is usually gentler than most ingoing ones. Almost all the miniature deltas are built up in a westerly direction. At rising water when water runs into the lagoon it has to move against a bottom slope in the channel. At bankful stage, when water passes over the levees and meets the water previously canalized into channels and lagoons very complicated flow and sedimentation patterns may arise (see for example Fig. 66, lagoon 105, area E 5).

Almost all miniature delta channels meander in a much more typical way than most of the larger delta distributaries. When the channels are short, maximum sedimentation is probably located in the part where the current of the channel meets the still water of the lagoon. As the channels grow longer the water velocity is reduced already in the channel. Therefore at least the coarser part of the sediment load does not reach the lagoon but is deposited in the channel which becomes narrower and shallower. At the miniature delta front the channel is unstable and a new high water may erode a new channel into the recently deposited sediments. Erosion is not confined to the actual channel since the water easily passes over the comparatively low and ill-defined levees at the miniature delta front and then spread over a larger area.

Colonization of a channel by vegetation usually starts at the miniature delta front in connection with the delta front bars. The channel could in this state be a 1–2 dm deep scar in the pioneer-vegetated bar. Eventually swamp vegetation develops across the channel and the open water area of the lagoon and acts as a low-water threshold for the lagoon. As large parts of the channel are no longer appreciably influenced by streaming water and the sediments are moved too a much lesser extent, vegetation invades also other parts of the channels. This again accelerates the sedimentation in the channel, since vegetation slows down the water velocity and keeps the deposited sediments in place.

Meandering lagoon channels with a westerly direction often have a broad swamp zone between the channel and the open water area, for example lagoons 36, 52 and 53. In lagoon 36 the channel end is around 1 dm deep and overgrown by a mixed graminid swamp (see section 5.2.4). In small lagoons surrounded entirely by deltaic deposits or bordered by only one or two islands of till, the lagoon channel will be closed when the (energy) gradient is reduced to ineffectiveness (Dahlskog et al. 1972).

The original depth of the basin and the position of the channel have a great impact upon the process of closure of a channel. In large old lagoons adjacent to the surrounding mountains (see Fig. 4: lagoons 16 and 17) the channels are usually comparatively long and lack or have a low permanent low-water threshold. Enclosed behind the meander lobes of these channels there are small interlevee basins with a high summer water-level. The position of these large lagoons along the mountain sides gives them a catchment area of their own. At low water discharge in the delta distributaries no water passes into these lagoons, but they still receive some water from the surrounding mountain sides. These affluents are small brooks and seepages but after rains also above-ground run-off occurs. Therefore, even when the river is low and not changing its water-level, water passes out through the channel keeping it fairly deep and wide. The large water volumes of these lagoons affects the efficiency of the channel, since much larger volumes have to pass out or in per unit of time than in the smaller lagoons. The discharge of a stream is a direct function of the area of the drainage basin above the point at which discharge was measured (Allen 1965).

3.3.2. Channel-distributary junction

At the connection between a lagoon channel and a delta distributary the entrance is originally open at mean water-level. As pointed out earlier, the opening is usually situated in the eastern (downstream) part of an interlevee basin either on the northern or southern side of the basin. Fig. 12 shows schematically the development of a distributary closure after bifurcation, a commonly appearing process in the Laitaure delta, and directions of the currents, the gradual narrowing and possible closing of a distributary.

A lagoon channel usually has a very small angle to the distributary while at a delta bifurcation the angle is large between the two streams. Fig. 13 shows different processes at the channel-lagoon junction. The lagoon channel is usually directed opposite to the general flow while a delta distributary, although often angled and curved, has its water flowing in the prevailing direction. Moreover, water passes in both directions in a lagoon channel, a phenomenon which cannot occur in the normal distributaries in freshwater deltas.

Very few lagoon channels are closed at the channel-distributary junction. This implies that the low-water threshold keeping up the water-level in the lagoon is not situated at the connection between lagoon channel and delta distributary, but near the point of in- and outflow of the lagoon. Frequently there is a point bar that partly closes the entrance but it hardly ever persists. This bar could work as a temporary threshold

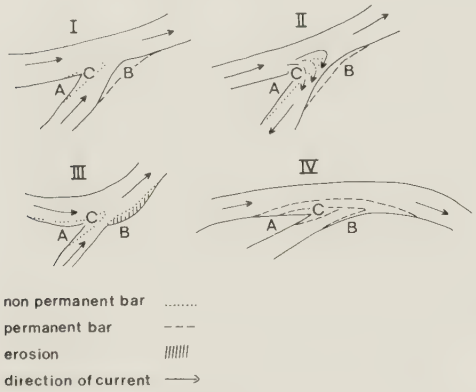


Fig. 13. Channel-distributary junction. The direction of currents at raised and lowered discharge, and erosion and accumulation processes at the connection between lagoon channel and delta distributary are shown. I. Direction of current at lowered water discharge; bar C is commonly found in the stream direction. II. Direction of current at raised water discharge; bar C could be eroded away at the inflow of water into the channel; this may also happen when the water from the lagoon passes into the distributary again at lowered water level; the shore B might also become eroded due to the helicoidal flow. III. A junction at a concave bend; erosion at both A and B commonly occurs; the bar C seldom becomes covered by vegetation since it is often overtopped by streaming water and thus easily eroded. IV. A junction at a convex bend; the bar C could become permanent and the entrance could become closed due to point bar development.

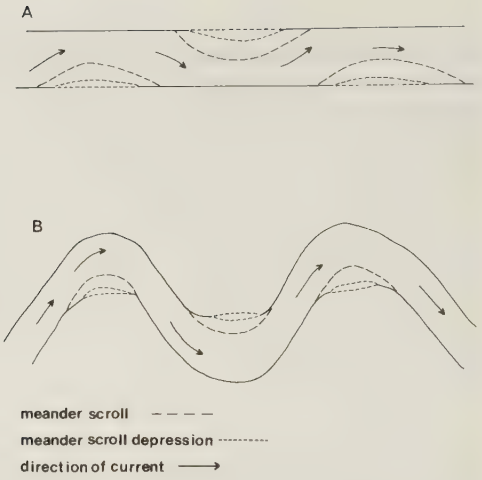


Fig. 15. Stream channel pattern. The current of the water is meandering in spite of the straight channel. A: straight; B: meandering (partly from Allen 1964).

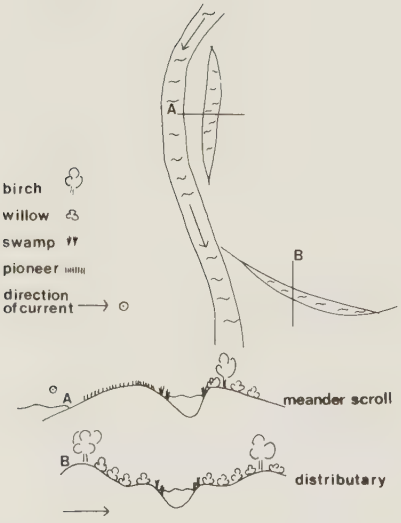


Fig. 14. The position and general appearance of a meander scroll depression (A) and a closed distributary (B). See Fig. 4 for a typical closed meander scroll depression (lagoons 48 and 49) and a closed distributary (lagoon 78). The vegetation zones and the general direction of current are indicated.

preventing water from passing into the channel at low but rising water-level. The higher and more permanent the bar becomes, the slower the miniature delta in the channel grows. A lagoon channel may end in a closed-off or almost closed-off delta distributary. The connection may also be situated on the convex shore of a meander bow. In these cases the point bar could become permanent and close off the lagoon. In the Laitaure delta, however, almost all channel-distributary junctions are situated along the concave banks of the delta distributaries.

3.4. Closed delta distributaries and meander scroll depressions

Former distributaries (e.g. lagoons 64, 65, 66, 67 and 78 in Figs. 4 and 67) and meander scrolls (e.g. lagoons 48, 49 and probably 90 in Fig. 76) give rise to long and narrow lagoons. Mostly the open water area is small and derives from former deep pools. These lagoons have rather steep borders as compared with interlevee basin lagoons. The shores are made up of coarse sediments as also are the bottoms of these lagoons. The vegetation zones are usually narrow (see Fig. 14). In some cases it is difficult to tell whether a lagoon is a former meander scroll depression or a former distributary, in cases when the closure was performed before the oldest photographic evidence (1899), but it is possible to classify the lagoon by studying the surrounding vegetation.

The meander scroll depressions are enclosed between a stable levee or an old point bar and a new point bar or meander scroll (see Fig. 15). They extend in the stream direction and frequently there are systems with several depressions and scrolls adjacent to each other. The closure is comparatively fast as the inflows are situated in the stream direction. The depressions could also be totally filled with sediments. Closed distributaries, on the other hand, are formed between almost simultaneously built-up levees. One of them might be a few years older but they often grow to the same height (see transect 38 in Fig. 21). They usually extend at an angle to the stream direction and are closed by bars formed upstream from the cleavage bar and by longitudinal bars (see Fig. 38, the closure of the distributary forming lagoon 78). No real oxbow lagoons exist in the Laitaure delta but a few channels have been cut-off giving the appearance of a semi-circular lagoon.

4. Vegetation

There are considerable differences in the distribution, structure and composition of the vegetation in and around each lagoon as well as between different lagoons. The structure and physiognomy of the vegetation is mainly a consequence of land formation processes, of the age of the vegetation and of the water regime in the lagoon adjacent in the past and present.

4.1. Sampling of vegetation

Around some lagoons the vegetation and its zonation are uniform over large areas, but in others the variation is large and to describe the variation in the zonation, one transect almost every hundred metres would be needed. The composition of the vegetation has been analysed in belt-transects and rectangular plots. Transects have been used to clarify different zonations and plots to study succession in more homogeneous areas. The location of the transects and plots has been subjectively chosen in order to describe different types of zonations and vegetations. Usually the transects begin in areas only reached by extreme high water and pass out into the open lagoon. The rectangular plots measured 2 m times 5 m with 10 small squares along each of the two long sides. These analysed small squares were always 0.5×0.5 m^2 (0.25 m^2). Similarly, the belt trans-

Fig. 16. The Laitaure delta. Aerial photograph by *Rikets allmänna kartverk* (the Geographical Survey Office), June 18, 1954. Water-level 494. 3 m above M.S.L. Approximate scale 1:37,000.

ects were 0.5 m in breadth, but in a few cases 2 squares of 0.25 m^2 have been analysed beside each other, giving the transect a width of one metre. The width of 0.5 m is too narrow to show in full the composition of the vegetation at a certain level, since the "minimal area" (Mueller-Dumbois & Ellenberg 1974) is much larger, but to use larger squares would have given less sharp zone boundaries.

The cover of field-layer species as well as shrubs and trees has been estimated according to a percentage scale. Cover values of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 % have been used. These values represent the mean of the upper and lower cover class limits. In a few cases the vegetation in the 0.25 m^2 squares in very long transects has been estimated using the following scale: 1 sparse, 2 frequent, 3 dominant.

In addition, the shrub- and tree-layer species have been classified into four classes according to their vitality: Class 0, totally dead shrubs either found only as remnants down in the swamp vegetation or still reaching above the swamp level as white sticks. Class 1, almost dead willow shrubs in which the necromass of dry twigs exceeds that of the living biomass. Class 2, the willow shrubs are still alive but the shrub layer has started to become thinner and the amount of leaves to decrease. Class 3, vital shrubs (in a closed willow stand the cover value often reaches many 100 %).

It has not been possible to analyse belt-transects around all delta lagoons. In the lagoons not intensively studied the structure and vegetation composition have been determined from air-photos. However, all lagoons have been surveyed by boat and by foot. I have walked around all of the interlevee basins making frequent detours into the swamps and as far into the lagoons as possible, with waders, noting the structure of the vegetation and making lists of species.

Fig. 17. The Laitaure delta. Aerial photograph by *Rikets allmänna Kartverk* (the Geographical Survey Office), 1965, eastern part of the delta. Comparatively high water-level. Approximate scale 1:34,000.

Fig. 18. The Laitaure delta. Aerial photograph by *Rikets Allmänna Kartverk* (the Geographical Survey Office), 1966, western part of the delta. Comparatively low water-level. Approximate scale 1:40,000.

The vegetation has mainly been analysed between July 1st and September 1st. I have re-analysed many of the transects and plots and tried to do this at the same time every year. However, this goal was not always possible. The vegetation analyses of 1973, for example, are not fully comparable with the rest, since the sediments deposited from a comparatively late high water (18 July 1973) buried the field-layer vegetation almost completely in some areas. The transects and plots were levelled in reference to the delta level chain and to different water-level gauges that could be of interest.

The vegetation analyses presented in this paper are all, except plot 4 and transect 4, situated between a levee crest and a lagoon or a bay, and the vegetation types distinguished are only valid for the side of a levee facing an interlevee basin. The vegetation types analysed have been selected for various reasons.

The choice of sampling places (plots and transects) is discussed below and the places are characterized briefly.

Plots 13 and 10: In the swamp zone. In plot 13 *Carex aquatilis* dominated totally on pioneer land in contrast to plots 11 and 12 (not presented here) which were dominated by *Deschampsia caespitosa*. The differences in level between plots 11, 12 and 13 were small. Plot 13 was laid out 10 m from and around 25 cm below the last willow shrub along the gradient. Plots 9 and 10: Chosen at the same time. Plot 10 was dominated by *Equisetum fluviatile* and the single willow shrub in the plot did not reach above the swamp vegetation. Plot 9, situated 20 cm above plot 10 and in the willow zone, had a swamp vegetation consisting of sedges and *Poa pratensis* coll.

Plots 9 (see above), *4, 5, 15, 16 and 19:* In the willow zone. Plot 4: dominated by *Calamagrostis neglecta* but with a high frequency of young willows, was chosen together with plot 5 dominated by low willows and with *Pedicularis sceptrum-carolinum* in the field layer. Plot 4 is situated on the distributary side of a levee crest 1 to 20 cm below plot 5, which was considered older than plot 4. Plots 15 and 16 were chosen together, plot 16 lying about 30 cm above and 30 m downstream from plot 15. The latter is located in an opening in the otherwise densely willow-covered area, the willows being around 2 m high. In plot 16, on the other hand, the willows were low (0.5 m) and scattered birches could be found in the area. The field layer in plot 15 is made up of swamp species (mixed graminid swamp) while in plot 16 the field-layer vegetation is sparse and lichens (*Peltigera* spp.) are dominant. Plot 16 could be younger in spite of the level 30 cm above plot 15. Plot 19 was chosen together with plot 20 (situated in the birchwood and not presented here). The willow vegetation in plot 19 was very dense and there were

Fig. 19. The swamp-willow subzone along the border of a sheltered bay of Lake Laitaure. Scattered willow shrubs in a mixed graminid swamp (4.5.1.1).

few field-layer phanerogams but the ground was completely covered by mosses. A few solitary birches grow in this willow-covered area.

The transects have been laid out to show different kinds of zonations, as follows, but only those squares of the transect which are relevant for the aims of this paper, i.e. analyses of swamp and willow vegetation in an interlevee situation, have been used in the tables.

Transect 4: Describes the zonation from a levee covered with grey alder *(Alnus incana)* passing a meander scroll depression. The transect gives an example of high and closed willow vegetation on comparatively dry ground.

Transect 11: Laid out over a high and steep levee exposed to upwelling water, on a concave shore, due to helicoidal flow (Axelsson 1967, among others). The material in the levee is very coarse, mainly gravel and coarse sand. The top material is wind-blown sand. The levee is high enough to protect the willow zone from being flooded from the distributary at any water stage.

Transect 12: At the shore of lagoon 85 where the slope of the ground was very weak and no distinct levee crest could be found. Low willow shrubs covered the part close to the distributary while the shrubs towards the lagoons were higher and more vital.

Transect 17: Originally analysed together with transects 16 and 18 (not presented here) to show pioneer vegetation at different exposures to streaming water. In 1974 transect 17 was enlarged over the narrow levee and down to the open water of lagoon 84 in which a dying-off of the willow zone had been observed.

Transect 21: In lagoon 51 where *Hippuris vulgaris* was found growing in 3 dm deep water in a dying willow zone.

Transect 22: Describes the zonation in a young shallow lagoon with an abrupt boundary between the willow and the swamp zones.

Transect 23: Laid out over an area which I regarded as old but still influenced by a fluctuating water level.

Transect 24: Crosses a levee with dying birches.

Transect 33: Close to transect 24; shows a complete zonation from a levee only to some degree influenced by the raised water-level in lagoon 105 passing a totally degenerated willow zone and a lagoon developed from a swamp vegetation in a closed distributary to a levee with dying birches and then out into the actual reedswamp of lagoon 105.

Transect 38: Laid out to show the variation in the ground level and vegetation zones across a closed distributary between lagoons 69 and 80. The vegetation in the swamp zone in lagoon 80 was analysed.

4.2. Vegetation types, their development and characteristics

The classification presented here is founded on the structure of the vegetation, the physiognomy of the different vegetation layers, on indicative species and on species frequencies. The number of species occurring in the delta is comparatively small and there are few truly differentiating species except on the islands and the higher levees where a number of terrestrial species add to the amphibious flora.

The different main vegetational types (swamp, willow thicket and birch vegetation) have been classified according to their place in the zonation from lagoon to levee crest, and according to their occurrence in open or closed lagoons. This classification might seem a bit premature, since it is derived from the intensively studied lagoons presented in section 5.2,

but it has been necessary to distinguish and characterize the vegetation types in this way in order to simplify the description of the vegetational development in these lagoons. This classification has to be regarded as only giving a rough indication of the situation, since I consider the development to be largely continuous. There are, however, some species combinations with a longer duration than others just as there are sudden interruptions in the successions, which make stages difficult to delimit.

4.3. Aquatic vegetation

Truly aquatic species (*sensu* Iversen 1936) are few but three structurally different kinds of ordinary lagoon vegetation can be distinguished. In addition, the vegetation of lagoon 1, mentioned below, is in all respects different from most of the other lagoons in the delta. However, similar conditions are found in a few other small lagoons, having contact with the surrounding mountain slopes or with till.

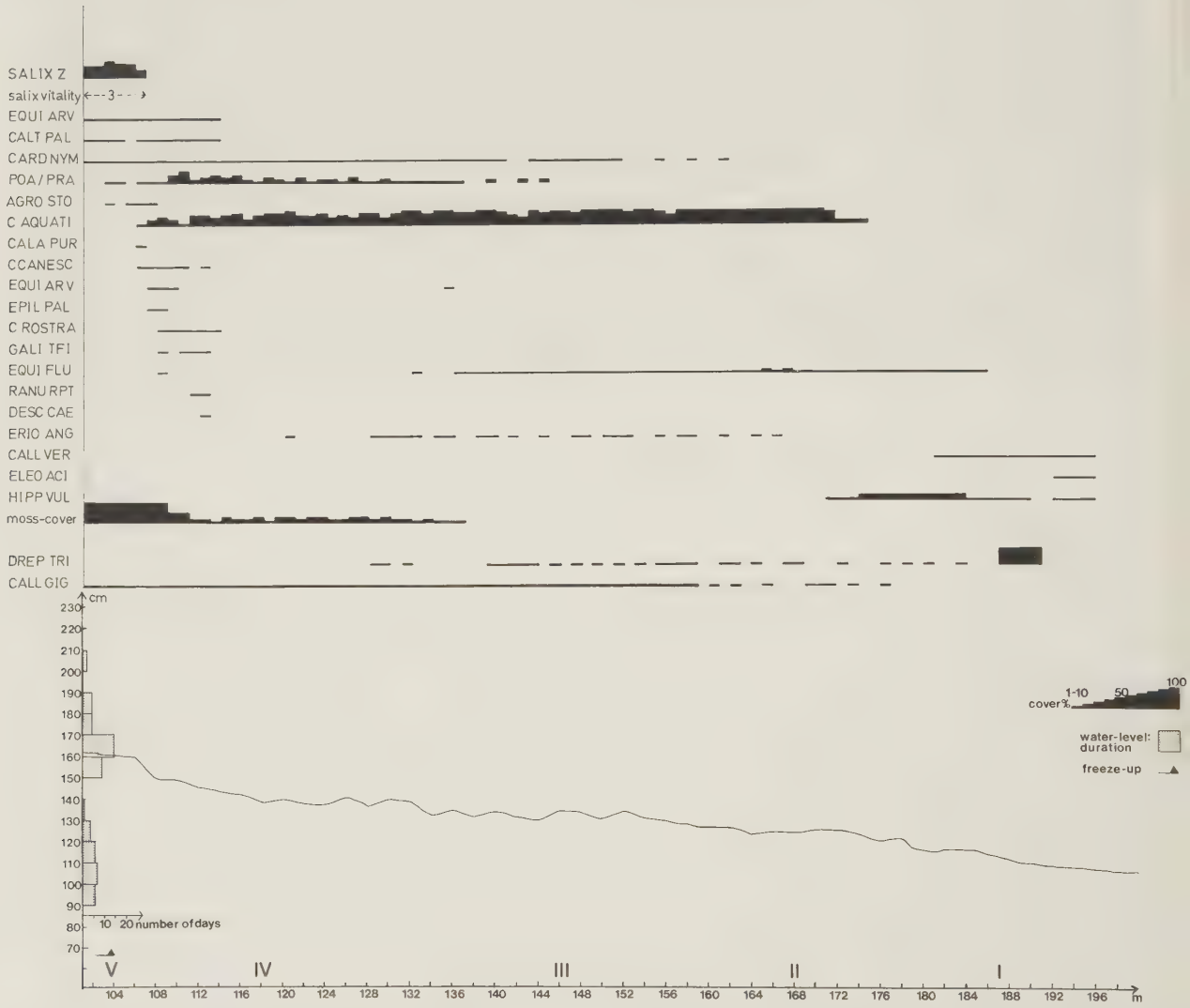


Fig. 20. Vegetation belt-transect 38 in lagoon 80 shows the swamp vegetation in an open lagoon without channel (for location see Figs. 4 and 38). The vegetation was analysed in 0.25 m² squares but in the Fig. every other square represents one metre. The border between the willow and swamp zones is sharp and the transect begins at this border. A sod can be found in places and is 3–7 cm thick. The water-level duration and the water-level at freeze-up in the lagoons in 1973 (triangle) of gauge 1 in the distributary Kuoutätno are shown.

Vegetation types along the transect. I. *Eleocharis acicularis – Subularia aquatica* vegetation (4.3.1); II. Reedswamp without sod (4.4.1.1); III. Mixed sedge swamp without sod; IV. Mixed graminid swamp (4.4.3.2) in places with small willow shrubs (AIII); V. Moss-covered swamp (4.4.3.1). Dominating mosses in this transect are *Bryum pseudotriquetrum, Campylium stellatum, Hypnum lindbergii, Drepanocladus uncinatus, Marchantia polymorpha* and *Sphagnum squarrosum*. VI. Tall willow shrub vegetation with a mixture of telmatic and terrestrial species, probably initiated in swamp vegetation.

The above-mentioned three main types are (i) *Eleocharis acicularis – Subularia aquatica* vegetation, (ii) *Potamogeton alpinus – Sparganium* sp. vegetation and (iii) *Drepanocladus trichophyllus – Calliergon giganteum* vegetation.

In lagoon 1 a quagmire dominated by *Sphagnum* spp. has developed from the shore. This lagoon is the deepest in the delta, around 3 metres. It is the only site where *Menyanthes trifoliata* is found, and as to water plants this is true for *Isoetes lacustris* and *Myriophyllum alterniflorum* as well. Reiersen (1942) and Lohammar (1938) regarded *Myriophyllum alterniflorum* to be sensitive to frost. This is probably the cause of the restricted distribution of the species in the delta lagoons.

Eleocharis acicularis – Subularia aquatica vegetation

See belt-transect 38 in Fig. 20; belt-transect 22 in Fig. 22.

Structurally this kind of vegetation is prevailingly a rosette (isoetid) vegetation. Other non rosette-forming species, for example the long-shoot species *Callitriche* and *Hippuris*, occur with comparatively short stems. Four species occur regularly in this type. *Eleocharis acicularis* and *Subularia aquatica* do not grow in any other type, but *Ranunculus reptans* and *Callitriche verna* also appear in other types of vegetation. *Hippuris vulgaris*, *Drepanocladus trichophyllus* and *Calliergon giganteum* are often, especially in high water years, found in this vegetation type (see belt-transect 38 in Fig. 20).

This vegetation dominates on bottoms which are regularly dried out and situated in a backwater. At the delta front only sheltered bays are covered by vegetation of this kind because as soon as the speed of the current is appreciable the bottom substrate will be predominantly sand (finer fractions are swept away) and no vegetation at all will be found. In the lagoons *Eleocharis – Subularia* vegetation is often found on the

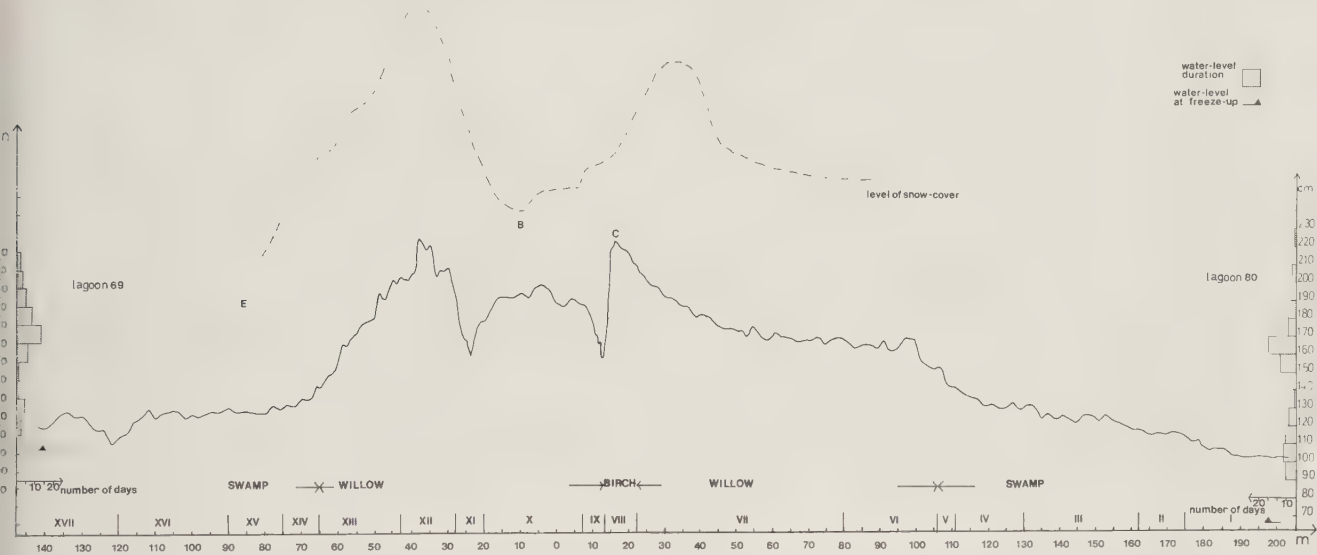


Fig. 21. Transect 38 crosses the closed distributary southeast of lagoon 69, which created the western border of lagoon 80, and passes into lagoon 80 (for location see Figs. 4 and 38). The areas B, C, and E are described in section 5.2.1 and shown in Figs. 38, 39, 40 and 41. The water-level duration and water-levels at freeze-up (triangles) of lagoon 69 and gauge 1 in the distributary Kuoutätno (an approximation of the water-level duration in lagoon 80) are shown. The snow-depth was measured 23 April, 1973.

The vegetation along the transect has been only roughly recorded. Classification: I–V. See Fig. 20. VI. Tall dense willow shrub layer with a mixture of telmatic and terrestrial species in a sparse field layer (4.5.2.3). VII. Tall willow vegetation with a field layer dominated by terrestrial species (4.5.3.2). VIII. The levee crest is covered by 3–4 m high birches, with a maximum diametre of 10–12 cm; the area is and has been highly influenced by wind-blown sediments; to be noted: the levees bordering the distributary reach the same height but only the one built-up by wind-blown sediment has birch as dominant shrub and tree. IX. The deep-pool of the closed distributary; the bottom is covered by mosses and in certain years the pool probably dries up. X. The vegetation might be classified as low willow pioneer vegetation with scattered birches (4.5.3.1) but here birch shrubs dominate; the ground is mainly built-up by wind-blown sediment and is in fact too high for what is normal for low pioneer willow vegetation; the field-layer vegetation is a mosaic of dune vegetation and vegetation types characteristic of birch-covered levees submerged at high water. XI. Lagoon 78, the deep-pool of the former distributary; the bottom is minerogenic and there is a narrow fringe of *Carex aquatilis* around the open water. XII. The levee crest is covered by high willows; birches occur but are rare; *Juniperus communis* forms a second shrub layer. XIII. Tall willow vegetation where telmatic and terrestrial species succeed along the gradient (4.5.3.2, 4.5.2.3 and 4.5.2.2) with dense shrub layer and scattered field-layer species. XIV. Area totally covered by sedge litter (4.4.3.1). XV. Mixed graminid swamp (4.4.3.2). XVI. Mixed sedge swamp on sod (4.4.2.2); sod rather thin, about 10 cm. XVII. Sedge reedswamp without sod (4.4.1.1).

backslopes of the levees along the miniature delta channels and in the vicinity of the channel-lagoon junctions where the water is shallow and the bed-load transportation limited. In deeper water in the open lagoons the turbidity probably restricts the distribution of these species. *Potamogeton alpinus – Sparganium* sp. vegetation may well be predominant in other parts of the lagoon.

Potamogeton alpinus – Sparganium sp. vegetation

Elodeids and nymphaeids (Thunmark 1931) dominate and characterize this vegetation. Together with *Potamogeton alpinus* and *Sparganium* spp. *Hippuris vulgaris* is very common. *Ranunculus peltatus* and *R. confervoides* also appear in this vegetation but are rare

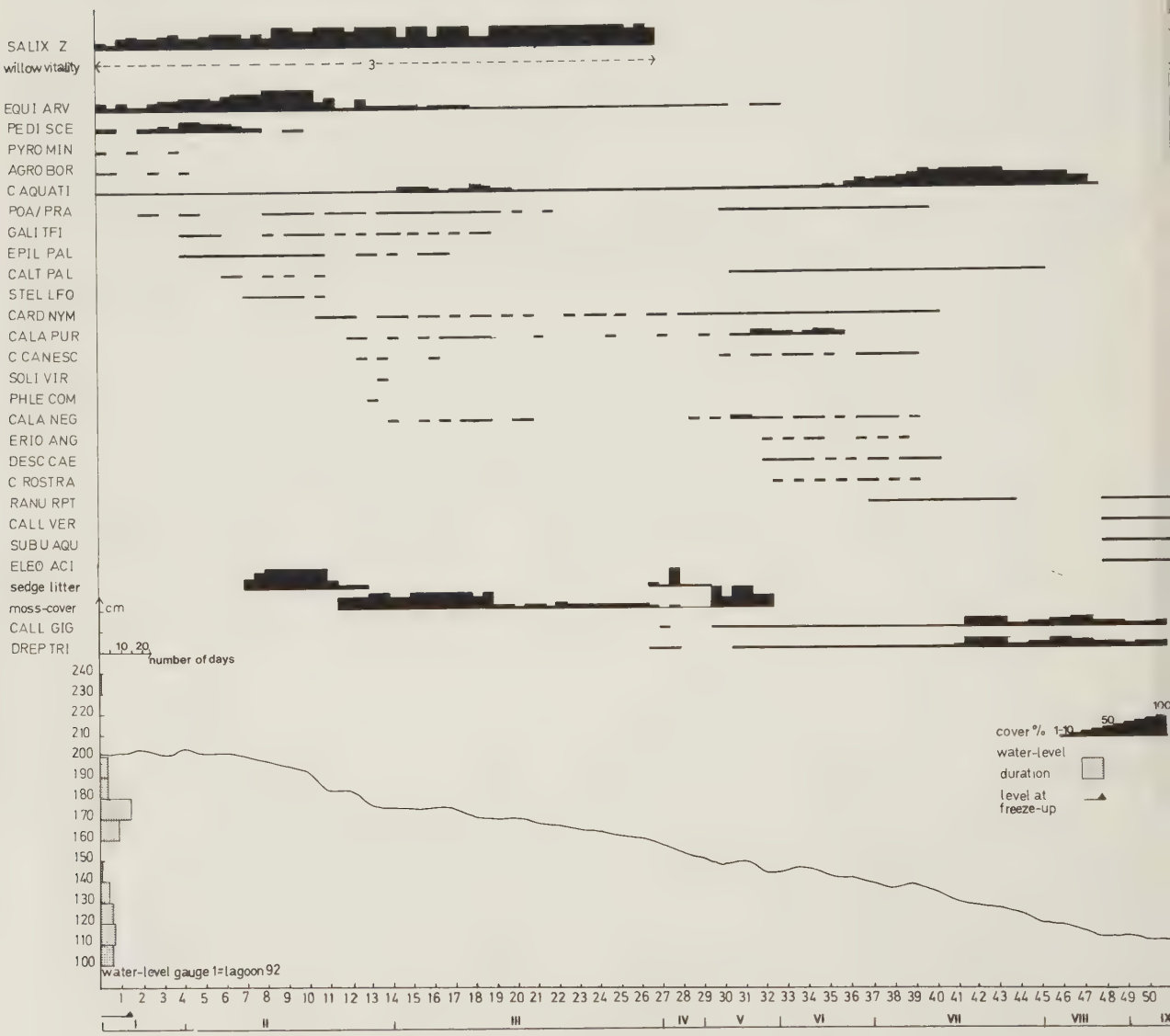


Fig. 22. Vegetation belt-transect 22 (for location see Figs. 4 and 49). Shows the zonation at a young shore in an open lagoon. It passes from the low willow vegetation on the levee crest bordering the distributary Årjeliätno to lagoon 92. The ground level has been measured. There is no sod, the ground being minerogenic along the whole transect. The water-level variation at gauge 1 is used as an approximation of the water-level duration in lagoon 92.

Vegetation types, the stages in the willow succession, Tables 3–5, are indicated (A, B, C and Roman numerals): I. Low willow pioneer vegetation with scattered birches (4.5.3.1, BIII, CIII); II. Tall willow vegetation with a mixture of telmatic and terrestrial species in the field layer (4.5.2.3, BIV); III. Tall willow vegetation with mainly telmatic species in the field layer (4.5.2.2, BV); IV. Litter-covered swamp (4.4.3.1); V. Moss-covered swamp (4.4.3.1); VI. Mixed graminid swamp (4.4.3.2); VII. Mixed sedge swamp without sod (4.4.2.1); VIII. Reedswamp without sod (4.4.1.1); IX. IX. *Eleocharis acicularis – Subularia aquatica* vegetation (4.3.1).

and are usually only found in the non-shallow parts of lagoons with a distributary connection, and not in closed lagoons. *Alopecurus aequalis* can also be found. *Callitriche verna* is frequent where the water depth is around 75–100 cm and the size of the lagoon small. It is especially common in closed meander scroll depressions. Small specimens of *Calliergon giganteum* and *Drepanocladus trichophyllus* are commonly found. Also *Nitella* spp. occurs.

This vegetation mainly covers the bottom in more or less closed lagoons with a relatively small water amplitude. In young, open lagoons it occurs in deep and calm parts. *Callitriche verna* and *Hippuris vulgaris* have the widest ecological amplitudes and can even be found growing in young frequently dried-out areas and in drowned willow shrub vegetation. The *Potamogeton alpinus – Sparganium* sp. vegetation is regularly grazed both by moose and by ducks which may explain why it is poorly developed in some years. The water temperature is also of great importance for the development of this vegetation (Dahlskog 1964, see section 2.3).

Drepanocladus trichophyllus – Calliergon giganteum vegetation

Two species, *Drepanocladus trichophyllus* and *Calliergon giganteum* constitute this vegetation type. They are very common in the delta and are regularly found on *Carex* tussocks in the reedswamp and in the open water in almost all lagoons. Sometimes they even fill the whole water volume of a lagoon and then they are recognized as forming a special vegetation type. The maximum length of the moss shoots measured is no less than 1.5 m (see Fig. 28), but as they die off basally most of the plant is dead. In a few cases these bryophytes form fens in shallow depressions.

This vegetation type is common in small closed lagoons which are often completely surrounded by swamp vegetation. Many of these lagoons have been formed from swamps by retrogressive development. The vegetation type never appears in large lagoons, which is probably due to the negative effect of the ice break-up in early spring in these lagoons. In small lagoons surrounded by swamp vegetation there are probably hardly ever any movements of the ice as the ice-covered area is small and not reached by streaming water, but in larger lagoons, which freeze solid to the bottom, the mosses are probably carried away with the ice. *Utricularia minor* in one case fills a very shallow lagoon (61) in the same way as these mosses do. It is also rootless and grows in a similar way to the two moss species.

4.4. Swamp vegetation

The swamp zone is considered to have its limits at the edge of a lagoon or a bay and to extend up to the first willow shrubs. However, swamp vegetation can also form the field-layer vegetation in the willow zone. There is a continuous gradient from higher to lower elevation of the land surface but it is possible to divide the swamp zone as well as the willow zone into subzones. The swamp zone is treated in three different parts: reedswamp, interjacent swamp, and swamp situated adjacent to the willow zone. These subzones do not necessarily have to be different steps in the succession (cf. Gleason 1927). In the early part of the succession the different swamp subzones in the Laitaure delta might be different steps in the same succession. Thus the reedswamp without sod might develop into the mixed sedge swamp of the interjacent subzone. This part in the succession is verified in plot 13 (see Table 2).

In the early succession the shoreward swamp is comparatively dry and the vegetation differs mostly due to exposure, but with age there is a development of a thick sod, sometimes made up of mosses. The shoreward swamp subzone in open lagoons is considered to have its limit where the first willow shrubs appear. The delimitation in a closed lagoon is more complex as even living willow shrubs have been seen growing underneath the water surface, thus in what appropriately should be classified as lagoon vegetation. When swamp vegetation has invaded the former willow zone and there is only about 10 % of cover of living willows left, the vegetation is classified as swamp vegetation but is still considered to belong to the willow zone as the ground could still be covered by roots and stembases of willows. The retrogressive successions usually start in

Table 2. Development in plot 13 (for position see Fig. 4) from a Carex aquatilis swamp to a mixed graminid swamp. The position of the rectangular plot is parallel with the shore. Square 1–10 (levee-crest close) and square 11–20 (lagoon-ward) represent different parts of the zonation. Square frequency is given in percent, characteristic cover as exponent.

square	1–10			11–20		
year	1971	1972	1973	1971	1972	1973
Calamagrostis neglecta	100^{4}	.	.	90^{5}	.	.
Ranunculus reptans	50^{1}	.	.	70^{1}	.	50^{1}
Equisetum palustre	.	.	.	20^{1}	.	.
Carex aquatilis	100^{58}	100^{71}	100^{27}	100^{53}	100^{56}	100^{23}
Cardamine nymanii	100^{1}	100^{1}	70^{1}	100^{2}	100^{1}	100^{2}
Caltha palustris	90^{1}	100^{1}	100^{2}	80^{2}	80^{1}	100^{3}
Deschampsia caespitosa	10^{1}	30^{2}	40^{1}	10^{2}	50^{2}	20^{1}
Equisetum arvense	40^{1}	.	10^{1}	40^{1}	.	20^{1}
Poa pratensis coll.	.	20^{1}	90^{5}	10^{1}	40^{1}	100^{10}
Eriophorum angustifolium	.	10^{2}	30^{3}	.	.	10^{1}
Carex canescens	.	.	20^{2}	.	.	30^{1}
Eriophorum scheuzeri	.	.	.	.	10^{1}	.

Fig. 23. The swamp-willow subzone in a sheltered bay of Lake Laitaure. *Equisetum fluviatile* dominates.

Fig. 24. Young pioneer willow vegetation along a small distributary at the delta front. The shrubs in the background are higher and fringe an open bay. Till island I can be seen in the background.

old communities since some time is needed to raise the relative water-level. However, retrogressive successions can also start in comparatively young vegetation types since new land is continuously built up in the vicinity of the channels. Transect 23 in Fig. 25 and transect 21 in Fig. 26 show the zonation in old lagoons, transect 21 with markedly raised water-level.

4.4.1. Reedswamp vegetation

4.4.1.1. Reedswamp without sod

Carex aquatilis and *Equisetum fluviatile* are the only species with high frequency. In young very shallow lagoons the swamp vegetation abuts lake-wards to *Eleocharis acicularis – Subularia aquatica* vegetation. This kind of swamp vegetation fringes all open lagoons where the water-level fluctuates the whole summer (see transect 22 in Fig. 22). Usually the sod, predominantly of *Carex aquatilis*, is thinner towards the lagoon and the specimens are then rooted in the minerogenous bottom. The age and exposure of the swamp are of some importance because with age a sod will develop, especially where the swamp no longer expands out into the open water. Where the exposure is towards the west, an erosion notch is often formed, probably due to wave action. Ice action is, at least in some lagoons, less likely since there is usually no water in the swamp at freeze-up.

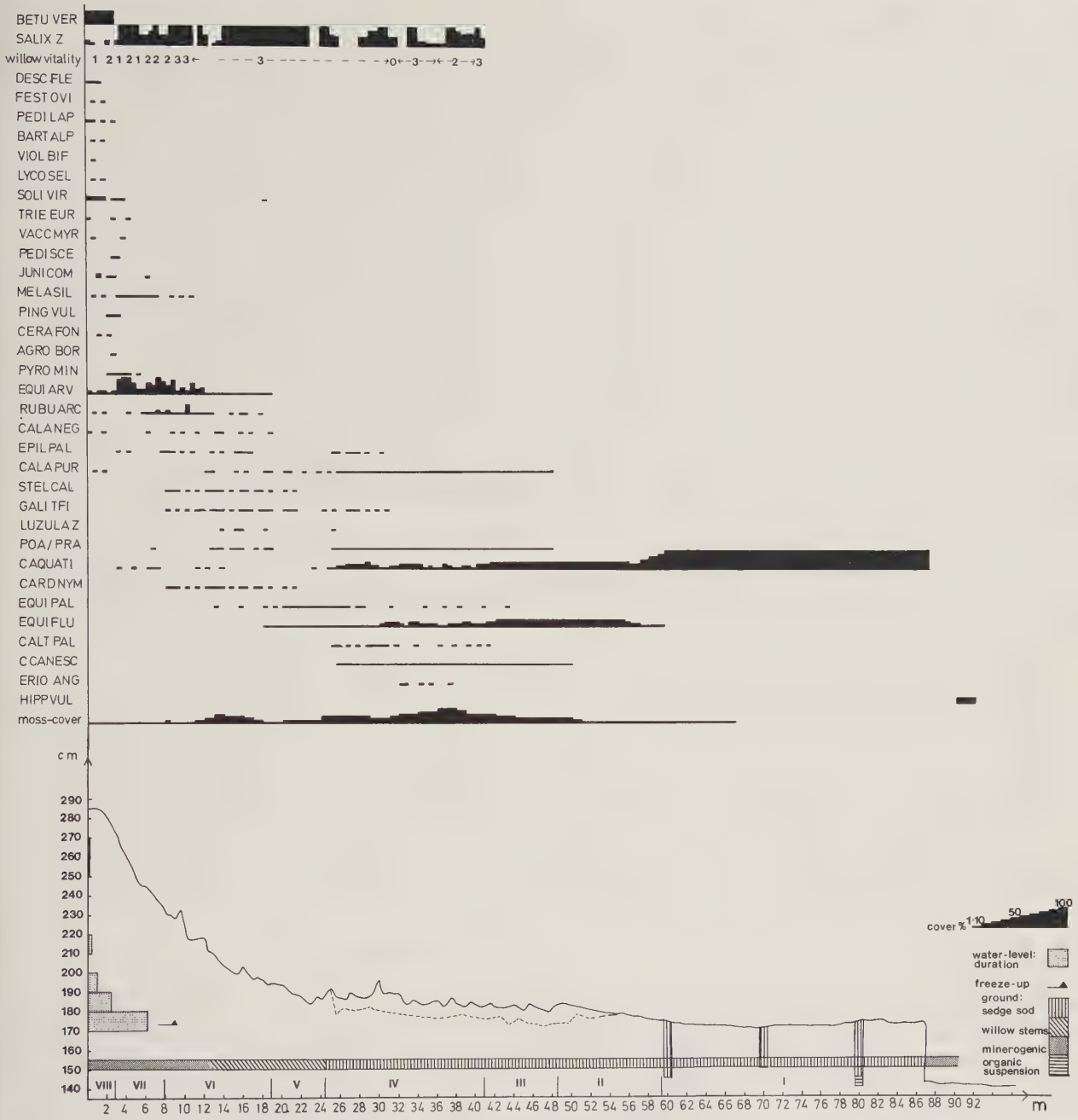


Fig. 25. Vegetation belt-transect 23 from the distributary Kuoutätno to lagoon 62 showing the zonation in an old lagoon where swamp vegetation has created a low-water threshold (for location see Figs. 4 and 41). The water-level duration in lagoon 60 is shown as an approximation of the durations in lagoon 62. The ground level has been levelled and is shown both for hummocks and hollows (hatched line). The composition of the ground is shown as also the thickness of the sod at three places. The breadth of the transect from 0–26 m is 1 metre (2×0.25 m² squares), but is here represented by only one row of 0.25 m² squares. From 26 metres and on the breadth of the transect is 0.5 metres. The cover of the field-layer vegetation in squares between 9–10, 11–12, 14–18, 19–22 and 23–24 has not been analysed as it is regarded identical with squares chosen as representative for parts of the transect. Hardly any species reached in this part a cover over 2 %.

Vegetation types, the stages in the willow succession, Tables 3–5, are indicated (A, B, C and Roman numerals): I. Sedge reedswamp on a sod (4.4.1.2), in the most lagoonward part floating and underlain by a highly organic suspension; II. Mixed sedge swamp on sod (4.4.2.2); III. Mixed graminid swamp (4.4.3.2); IV. Scattered willow shrubs in mixed graminid swamp (4.5.1.1 AVIII); V. Tall willow vegetation with mainly telmatic species in the field layer (4.5.2.3 A VII); VI. Tall willow vegetation with a mixture of telmatic and terrestrial species in the field layer BVI: VII. Tall willow vegetation with mainly terrestrial species in the field layer (4.5.3.3 BVI, CVIII): VIII. Comparatively narrow birch-covered levee.

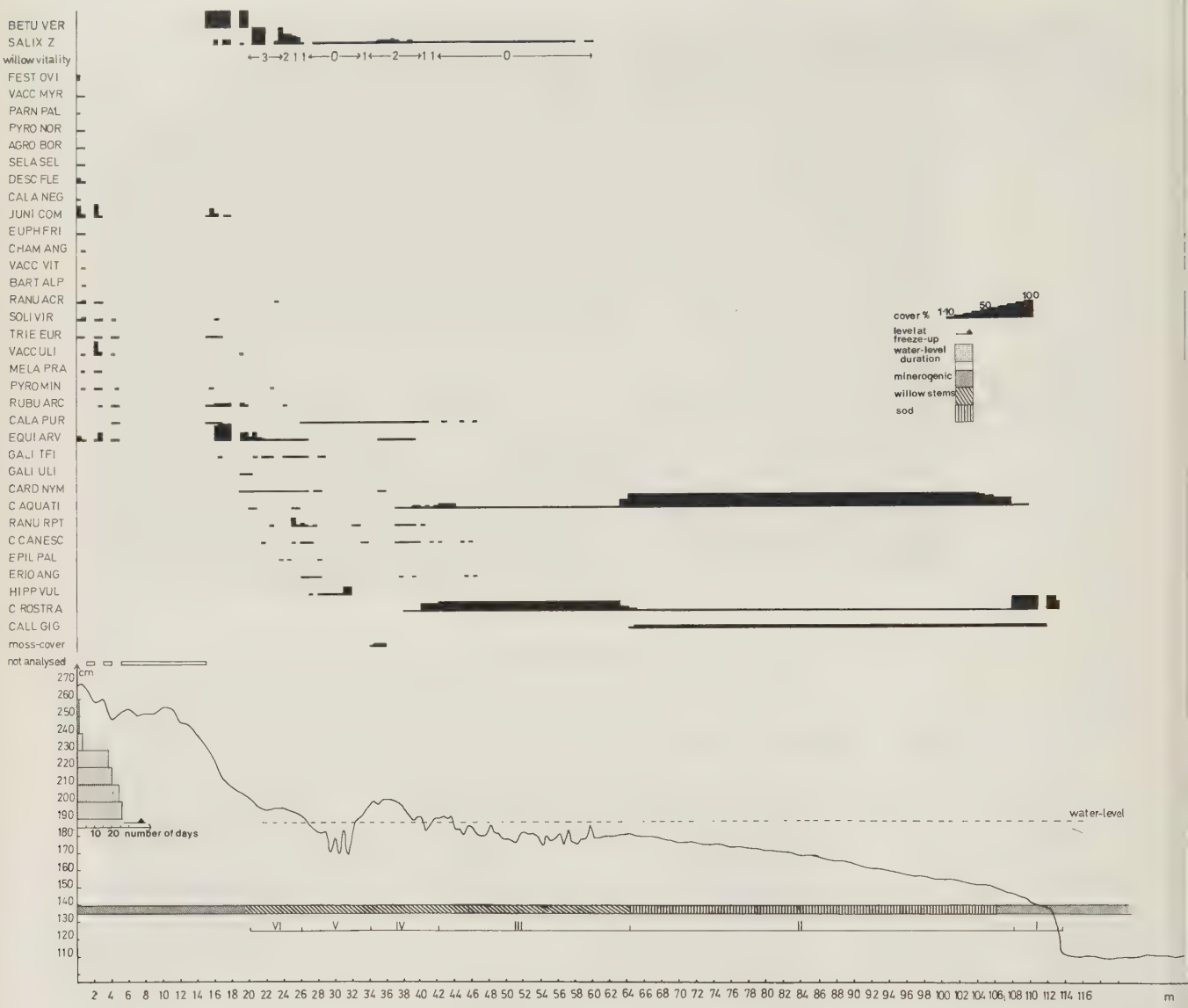


Fig. 26. Vegetation belt-transect 21 from the Kuoutätno to lagoon 51 (for location see Figs. 4 and 53). Parts of the birch-covered levee bordering the Kuoutätno have not been analysed, as indicated. From 0–34 m the breadth of the transect is 1 m, and from there on it is 0.5 m broad. The duration of different water-levels (14/6–24/7; 31/8–9/9 1973), the water-level at freeze-up of the lagoon and the ground structure along the transect are shown. The water-level at freeze-up is indicated by the hatched line. The water-level in lagoon 51 has been raised to an extent where the vegetation of the interjacent willow subzone has invaded the subzone close to the levee crest. The stages in the willow succession, Tables 3–5, are indicated (A, B, C and Roman numerals).

Vegetation types along the transect: I. *Carex rostrata* reedswamp (4.4.1.4). II. Mixed sedge swamp on sod (4.4.2.2). III. Scattered dead or dying willows in mixed sedge swamp (4.5.1.4), A VIII) some parts of the areas crossed by the transect are dominated by vegetation characteristic of the deteriorated closed shrub vegetation initiated in swamp vegetation (4.5.1.5 A VIII); the willows in the area are only found as white sticks. IV. Deteriorated willow vegetation dominated by sedges in the field layer (4.5.4.2 A IX); V. Deteriorated willow vegetation where open water covers the ground most of the year (4.5.4.3, B IX). VI. Tall willow vegetation with mainly telmatic species in the field layer (4.5.2.2) B VII); this is a vegetation type characteristic for the interjacent willow subzone but here it is situated close to the levee crest.

4.4.1.2. Sedge reedswamp on a sod

Carex aquatilis always dominates the sedge reedswamp on a sod but *C. rostrata* also occurs. The sod varies in thickness from 10 cm to 50 or even 60 cm in extreme cases. When the low-water level rises in a lagoon there is no possibility for the sedges to expand into the open water, the sod grows thicker and with a moderately raised low water-level the sedges do not die. In some places the sod is fastened in the bottom but may also quite often act as a floating substrate with probably the same genesis as a plaur (Antipa 1912; Rodewald 1943). Sods fastened to the bottom are usually found in young lagoons along shores where flooding and deposition of sediments are frequent and where the water-level in summer is kept somewhat above distributary low water-level and where the shores have a moderate slope. These sods are heavier than water and sink when flooded, which was also noted by Kulcyński from Poland (1949).

Rodewald (1943) describes the development of the plaur in the Danube delta. Due to the formation of methane underneath the rhizome blanket the net-work of mud, roots and rhizomes is lifted up from the bottom and the sod may become detatched as a result of heavy wave action, of even stronger gas formation during the summer, or of ice uplift during inundation in the early spring. In the Danube delta these detached pieces form floating islands. Such floating islands, usually with *Carex rostrata* dominant, are quite common in Swedish lakes used as reservoirs where the water-level rises strongly in spring and summer (Sjörs & Nilsson 1976; Sjörs pers. comm.).

There are no floating islands in the Laitaure delta. The detached or supposedly detached areas of swamp vegetation tend to sink or disintegrate, probably because of their content of fine sand and silt. Photos from 1973 revealed unidentified structures in the central part of lagoons 50 and 51 which have not been seen or photographed before or afterwards. In the same year considerable areas of swamp vegetation were disintegrated in these lagoons. The floating sods of the Laitaure delta might have developed through methane formation as methane commonly occurs underneath thick sods, but ice-uplift might also have been an agent in loosening the sod from the bottom. Sods that are not anchored to the bottom are underlain by a highly organic suspension and are heavy in open lagoons but in closed lagoons they may well float when flooded. These floating sods are found along the southern, northern and eastern shores and are thus protected from the prevailing western winds. McDonald (1955 p. 30) noticed that: "In some localities the upper layer of muck is very unstable, and the emergent vegetation almost forms a floating mat." The sedge reedswamps of the Laitaure delta described above constitute a turn from the progressive reedswamp succession towards the retrogressive type of succession. As long as the sod formation keeps up with the rise in water-level it could be regarded as progressive but with a slower sod formation it turns into a retrogressive type.

4.4.1.3. Tussocky reedswamp

Tussock vegetation is characterized by 30–40 cm high clumps of *Carex aquatilis* separated from the continu-

Fig. 27. *Carex aquatilis* clumps in lagoon 36. Remnants of a former continuous swamp. The water surrounding the clumps is about 70 cm deep; the bottom is firm. In the background, dead willows of area B4 (see Fig. 62).

Fig. 28. *Calliergon giganteum* from lagoon 63; about 1 m long shoots. The water volume in lagoon 63 is filled with *Calliergon giganteum*.

ous swamp vegetation by 60–100 cm deep water (see Fig. 27). These clumps are remnants of a former continuous swamp of which only rhizome-root clumps of *Carex aquatilis* are left. The clumps are evidently heavy enough to remain in place and high enough to endure the depth of water, which is normally too deep for *Carex aquatilis* in the Laitaure delta. It is, however, a comparatively short-lived vegetation type since the clumps disappear after some years, probably either dying from the high water-level or being disintegrated by ice or wind action. Whether these clumps are firmly rooted into the bottom or not is not known.

The tussocky vegetation is either called tussocky-swamp or tussocky-lagoon depending on the proportions between clumps and open water. Shoreward from the tussocky parts, the reedswamp is usually a sedge swamp, on a sod that sometimes floats. The tussocky reedswamp only appears in closed lagoons with a comparatively high low-water threshold and thus a fairly high water table even at distributary low-waters. It is found both in very small lagoons, where a slow thawing of the ice could be presumed, and in large lagoons where a violent break-up could be the agent in disintegrating the continuous swamp vegetation. Thus it is possible that *Carex aquatilis* could die only as a consequence of a water-level higher than normal. This vegetation type has to be regarded as retrogressive.

4.4.1.4. Carex rostrata reedswamp

The *Carex rostrata* reedswamp is characterized by a narrow zone of *Carex rostrata* rooted in the bottom, bordering the open water area, and with a 50–60 cm high step between the usually dominant *Carex aquatilis* swamp of the interjacent subzone and the *Carex rostrata* vegetation (see Fig. 29).

This kind of swamp vegetation occurs both in deep lagoons with steep shores and in lagoons formed in areas formerly occupied by swamp vegetation. It is very typical in small rounded lagoons in the western part of the interlevee basins situated directly behind a bifurcation. All lagoons where *Carex rostrata* forms the reed have a raised low-water level (see Fig. 26). This kind of vegetation has to be regarded as a step in the progressive succession although it is often found in lagoons where all other vegetation types could be regarded as parts of the retrogressive succession.

4.4.2. Interjacent subzone swamp vegetation

4.4.2.1. Mixed sedge swamp without sod

Carex aquatilis is usually the dominant species in the mixed sedge swamp without sod but *Carex rostrata* and *Carex canescens* are also frequent together with *Equisetum fluviatile*. *Equisetum fluviatile* may in places be dominant. Commonly appearing herbs are *Cardamine nymannii, Caltha palustris, Epilobium*

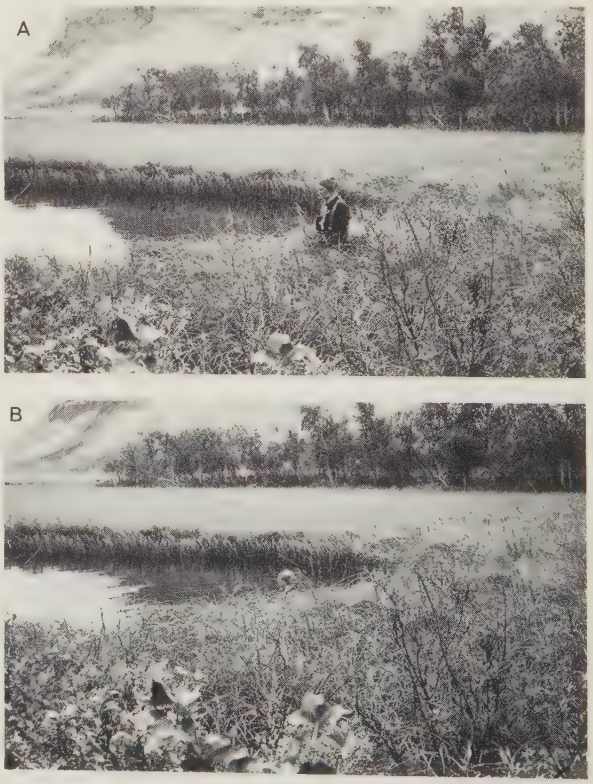


Fig. 29. The person on the two photos illustrates the difference in level between the sedge reedswamp on a sod (A) and the *Carex rostrata* reedswamp (B) in lagoon 89. The till ridge bordering lagoon 51 is seen in the background.

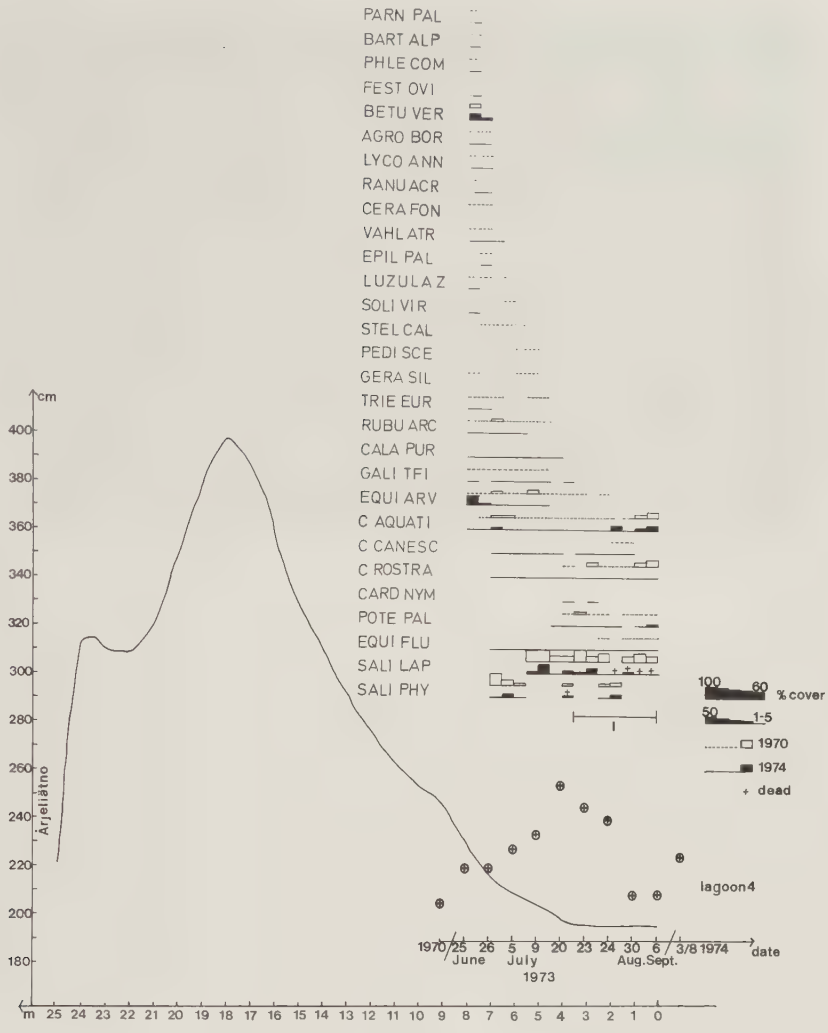


Fig. 30. The vegetation in the lower lagoonward part of belt-transect 11 in 1970 and 1974. The transect passes from the Årjeliätno to lagoon 4. A few water-level values (dots) are shown and there is a probable mean water-level between 200–210 cm as the values from July 20–24 reflect the extreme high water of July 18. The mean water-level might have risen during the 4 years as quite a large number of willow have died and many of the telmatic species have spread upwards along the transect, as also have the more terrestrial species. Squares 0–7 (0–3.5 m) illustrate willow vegetation where open water covers the ground most of the year (4.5.4.3), marked with I. In the succession (Tables 4 and 5), squares 1–7, 1970=B VII; 1–7, 1974=B IX; 7–12, 1970 and 1974=C IX.

palustre and *Ranunculus reptans*. *Sphagnum platyphyllum* may also be found.

4.4.2.2. Mixed sedge swamp on sod

The sod in the mixed sedge swamp on sod is usually up to 50 cm thick and the surface is slightly tussocky. Mosses are frequent and there is usually a co-dominance of *Carex rostrata* and *C. aquatilis*, in some cases together with *Equisetum fluviatile*. *Carex canescens*, *C. juncella* and *Eriophorum angustifolium* are also frequent but the latter is seldom fertile. *Cardamine nymannii*, *Caltha palustris* and *Epilobium palustre* grow on the higher tussocks. *Potentilla palustris* is rare.

The mixed sedge swamp without sod is usually found in young lagoons with the same water-level fluctuations as the distributaries, whereas the mixed sedge swamp on sod is found in older more or less closed lagoons. The development of the interjacent swamp subzone is progressive in the sense that the sod grows thicker. This growth may equal the rising water-level at least up to a certain point, depending on the rate of the rise of the low-water level (i.e. the rate of the closure of the lagoon). With regard to the effects of closure, the succession may be regarded as retrogressive as with time and further rises in water-level all species except *Carex aquatilis* disappear. The sod very often floats. When a reedswamp disintegrates into tussocky-swamp the interjacent swamp becomes reedswamp, usually with only *Carex aquatilis*.

4.4.3. Shoreward swamp vegetation

4.4.3.1. Moss-covered swamp

This kind of vegetation is dominated by mosses which totally cover the ground. The most common mosses are *Bryum pseudotriquetrum*, *Drepanocladus uncinatus*, *Calliergon cordifolium* and *Hypnum*

lindbergii. Scattered vascular plants occur. *Equisetum arvense, Carex aquatilis, C. canescens, Cardamine nymannii, Caltha palustris, Epilobium palustre, Galium trifidum, Poa pratensis* coll. and a few others are common. This vegetation is found along the shores of young open lagoons with gently sloping shores. It is also found between the willow shrubs where they grow at some distance from each other.

The subzone may be almost vegetation-free where the ground is completely covered by 1–2 dm thick litter of *Carex* spp. It is usually 2–3 m broad. The position in relation to the shore varies from year to year. Sometimes solitary specimens of various species occur. This vegetation type is common at the edge, along the eastern shore, of large open lagoons—thus with a westerly exposure—where litter is brought to the shore by the action of winds and waves. It is also found along parts exposed towards Lake Laitaure.

4.4.3.2. Mixed graminid swamp

The mixed graminid swamp contains almost all species which can endure a fairly frequent submergence of relatively short duration. Dominants are *Poa pratensis* coll., *Carex aquatilis, C. rostrata* and *C. canescens*. Also *Eriophorum angustifolium* and *Equisetum fluviatile* may dominate. There are scattered tussocks of *Carex juncella. Cardamine nymannii, Caltha palustris* and *Epilobium palustre* are always present. *Deschampsia caespitosa* and *Calamagrostis neglecta* occur in some places. Mosses are frequent but they usually grow on the bases of the graminids and only seldomly on the ground. With increasing age the ground becomes tussocky. The most frequent mosses are *Drepanocladus uncinatus, Hypnum lindbergii, Calliergon cordifolium* and *Bryum pseudotriquetrum*. Frequently appearing are also *Mnium rugicum, Philonotis fontana, Climacium dendroides, Aulacomnium palustre, Campylium stellatum, Cinclidium subrotundum, Polytrichum commune, Sphagnum squarrosum* and *Marchantia polymorpha*. In this zone can also be found *Tomentypnum nitens* and *Scorpidium scorpioides*. This very dense vegetation type is found along all open lagoons and is especially common at the delta front in sheltered bays.

4.4.3.3. Shoreward Carex aquatilis swamp

In this kind of swamp, *Carex aquatilis* dominates also shorewards, and only seldomly are other species present. The field layer is sparse and there is frequently open water present. In open young lagoons the shoreward swamp is always a mixed graminid swamp and, as the shoreward *Carex aquatilis* swamp is only found in old closed lagoons, it could be presumed that the mixed graminid swamp eventually develops into a shoreward *Carex aquatilis* swamp as a consequence of aging and rising low water-level.

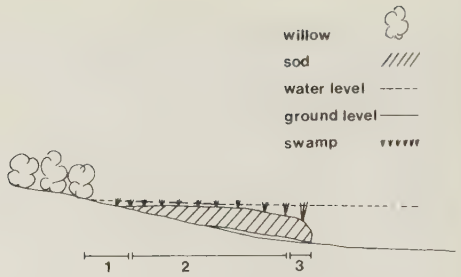


Fig. 31. Schematic diagram of vegetation in the swamp subzones and their relation to the mean summer water-level in closed lagoons.

1. Shoreward *Carex aquatilis* swamp (4.4.3.3); 2. Mixed sedge swamp on a sod (4.4.2.2); 3. Sedge reedswamp on a sod (4.4.1.2).

From the willow zone towards the lagoon there is a continuous thickening of the sod. The border between firm ground and the sod where this kind of vegetation is found is easily seen on IR-photos. The blue colour of the water is not seen in the swamp but is very distinct at the border between the swamp vegetation and the willow vegetation. The zonation is schematically shown in Fig. 31. This kind of border vegetation usually develops in old lagoons in places where there has always been a sharp boundary between the willow zone and the swamp zone and where the water-level is moderately raised, thus not to a level where the willow zone is totally drowned. A few shrub specimens can still be found in the swamp.

4.4.3.4. Eriophorum angustifolium swamp

The species combination is very characteristic in the *Eriophorum angustifolium* swamp. *Carex rostrata* and *Eriophorum angustifolium* dominate and *Carex aquatilis* might sometimes be missing. The ground may be formed by a *Carex* sod or made up of *Salix* roots and stems. This vegetation type can form a very narrow part of the shoreward swamp subzone (1–5 m) but it may also cover large areas in the former willow zone. The water depth can vary from a few centimetres to 50 cm at mean water-level in the lagoon (see belt-transect 33 in Fig. 33; belt-transect 21 in Fig. 26). Gill (1973b) considers *Eriophorum angustifolium* to be the only characteristic species of the decadent *Populus* community in the Mackenzie river delta. *Hippuris vulgaris* is usually found where the water is deepest and the graminid cover at the lowest, while *Potentilla palustris, Ranunculus repens* and *Petasites frigidus*

Fig. 32. A disintegrated levee in a swamp with sticks of dead willows, invaded by *Eriophorum angustifolium*.

grow at the border between the swamp zone and willow zone or on slightly higher spots among the sedges. *Galium palustre* and *Ranunculus reptans* may cover the dead *Salix* branches on the ground. *Caltha palustris* and *Cardamine nymannii* are also found. *Alopecurus aequalis* is comparatively rare in the delta but can also be found in the *Eriophorum angustifolium* swamp. This kind of vegetation is found in old closed lagoons which for some time have had a raised summer water table together with a raised autumn water table. The water-level is high enough to drown the willow zone inducing a retrogressive succession.

4.5. Willow vegetation

The willow vegetation is made up of several *Salix* species and hybrids between them. The most common species are *Salix phylicifolia, S. lanata, S. glandulifera, S. lapponum* and *S. glauca*. It is not possible to classify the willow vegetation according to species. There are a few locations in the delta preferred by certain species but usually they all grow together. *Salix phylicifolia* is, however, the highest and seemingly most tolerant willow. The limit of the willow zone is situated where single shrubs appear in the swamp. There is a vegetation gradient from high to low elevation in the willow zone. It can be divided into three main willow subzones. The zone close to the levee crest has coarse deposited material derived from the distributary. In the lagoonward or interjacent subzone the material mainly comes from the lagoon and is silty. Finally, there is the swamp-willow subzone (see Fig. 19). These distinguishable subzones do not start with the same vegetation stage and do not have the same successional stages. The willow zone is either initiated in (1) pioneer vegetation or in (2) swamp vegetation.

(1) Where there is a rapid land formation the deposited sediments are mainly sand and the pioneer vegetation is dominated by *Calamagrostis neglecta*. In that case the willow succession starts as a low willow shrub vegetation first dominated by *Calamagrostis neglecta* possibly followed by a 0.4–0.6 m high scrub with scattered herbs (see plots 4, 5 and 16 in Table 5). This kind of vegetation covers the levee crests and adjoining areas in the younger part of the delta. Thus it constitutes the starting point for the vegetation in the zone close to the levee crest and in the higher parts of the interjacent subzone.

(2) Where there is a gradual slow land formation, e.g. in backwaters, and where the sediments are usually fine sand or silt and deposited from suspended load the pioneer vegetation is dominated by *Carex aquatilis* and in most places develops into swamp vegetation. The willow succession then starts with solitary shrubs in the swamp which might then close up and form a high willow vegetation, or the willow specimens may remain scattered in the swamp vegetation. This pioneer vegetation will form the swamp-willow subzone and lower part of the interjacent subzone.

These differences in position, level and composition of the deposited sediments tend to be accentuated with time. The largest quantity of coarse material from each flooding will be deposited on the higher parts of the levees. As the levees grow higher, the frequency of direct distributary flooding carrying relatively coarse sediments to the lower zones decreases while backwater flooding from the lagoon, with deposition of small amounts of fine suspended material becomes most fre-

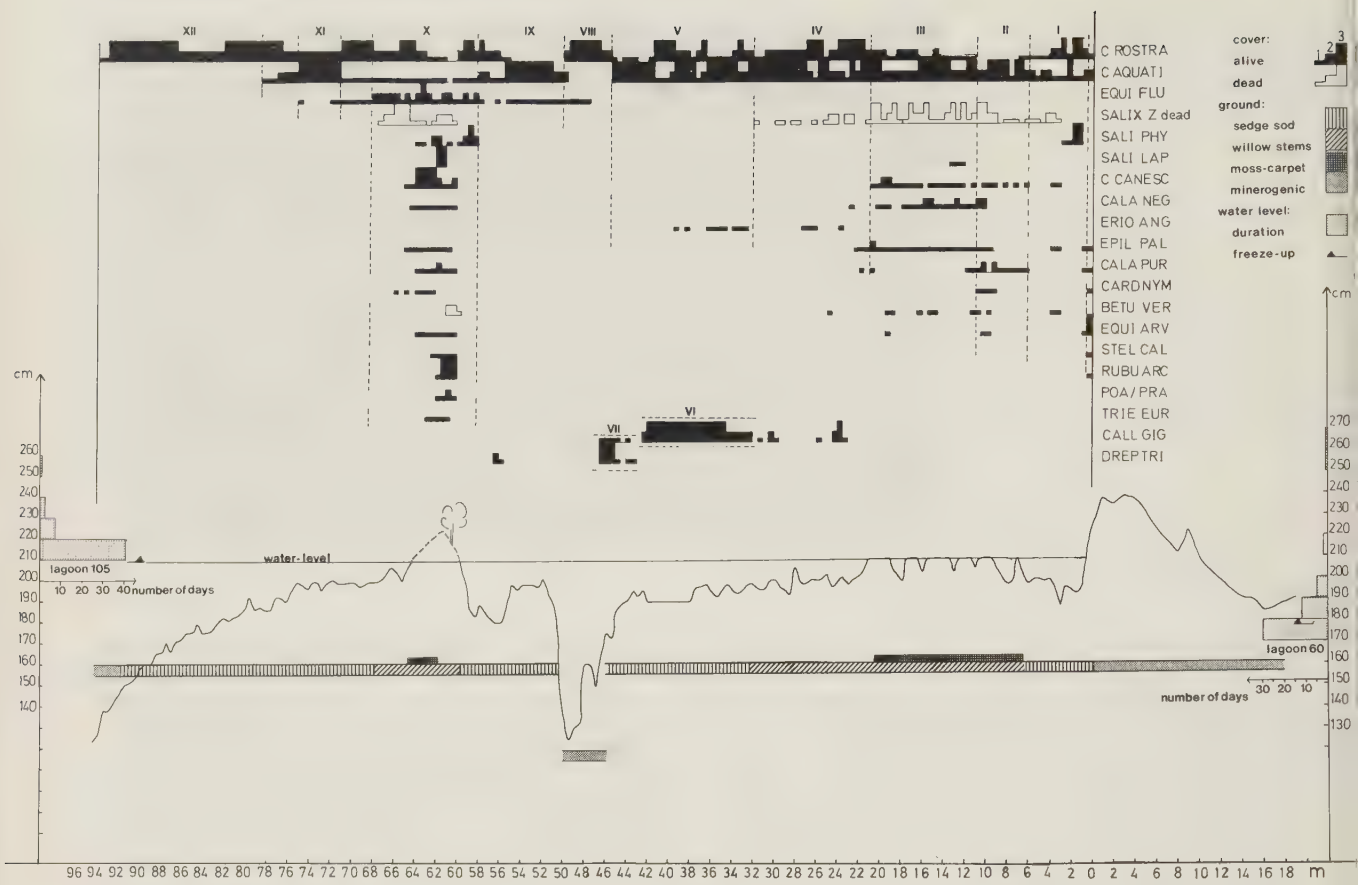


Fig. 33. Vegetation belt-transect 33 (for location see Figs. 4 and 67), starting from the levee separating lagoon 105 (left) and lagoon 60 (right) stretching into lagoon 105, passing an abandoned distributary and a levee covered by dead birches towards the open water of lagoon 105. The ground surface was levelled from the border between the swamp and willow zones in lagoon 60 to the end of the reedswamp in lagoon 105. The ground level of the birch-covered levee in lagoon 105 is impossible to measure properly (hatched); most of it consists of large moss tussocks or roots of birch or willow with open water in between. The variation in the structure of the ground is shown. The vegetation types according to the classification in the text is shown but also further described below. The ordinate shows the level of the ground transformed to the level of the water-level gauge in Lake Laitaure (150 cm=494.8 m above M.S.L). The water-level measurements were made in 1973, but the same stable water-level was recorded in 1972.

The first analysed square is situated on the minerogenic ground of the levee. The following species are exluded from the respective squares: *Ranunculus acris* (1), *Viola biflora* (1), *Agrostis borealis* (1), *Galium trifidum* (20, 21, 22), *Linnea borealis* (122, 123) and *Ranunculus reptans* (128).

Description of groups of squares distinguished and classification of the vegetation. The stages in the willow succession (Tables 3–5) are also indicated (A, B, C and Roman numerals):

Group I. Deteriorated willow vegetation dominated by sedges in the field layer (4.5.4.2, C IX). The ground is composed of sedge roots and rhizomes; it is situated lower than in groups II and III. Apart from *Carex aquatilis* and *C. rostrata*, all other species grow on the stems or horizontal branches of the willows.

Group II. Deteriorated willow vegetation with a bottom layer dominated by mosses (4.5.4.1, B VIII). *Carex aquatilis*, *Calamagrostis purpurea* and *Carex canescens* grow in the moss-carpet. *Carex rostrata* is not present.

Group III. Deteriorated willow vegetation dominated by mosses in the bottom layer (4.5.4.1, B VIII). *Carex aquatilis* dominates but *Carex rostrata* is always present together with *C. canescens*, *Calamagrostis neglecta* and *Epilobium palustre*. These squares represent the highest part of the area covered by dead willows and thus it can be presumed that the willow vegetation had been closed earlier.

Group IV. Scattered dead or dying willows in a mixed sedge swamp (4.5.1.4, A IX). *Carex aquatilis* codominates with *Carex rostrata* and *Calliergon giganteum*. The ground is formed by remnants of willow shrubs. There is now a continuous moss-carpet on top of the roots. The sedge tussocks grow directly at the dead stems and branches which together with the high water-level exclude more terrestrial species.

Group V. *Eriophorum angustifolium* swamp (4.4.3.4). *Carex aquatilis* still dominates over *Carex rostrata*. *Eriophorum angustifolium* is, however, frequently found. The ground is entirely made up of sedge roots and rhizomes.

Group VI. A total dominance of *Calliergon giganteum* is found between the tussocks.

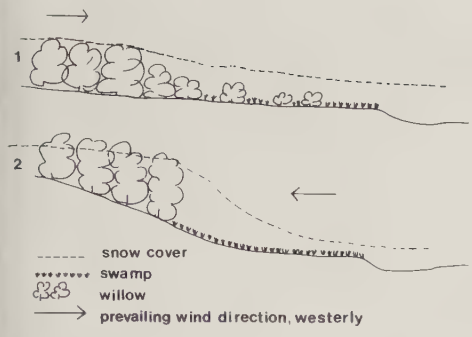


Fig. 34. The border between the swamp zone and the willow zone in young lagoons. Distribution of snow cover and prevailing wind direction is also shown. 1. In areas sheltered from the prevailing westerly winds the frequency and height of the willow shrubs diminish gradually and a swamp-willow subzone could be distinguished there. 2. In areas exposed to westerly winds there is generally a sharp limit of the willow zone. These structural differences of the willow zone border are only valid as long as the lagoon is open. When the water-level rises the border gets destroyed and becomes indefinite.

quent. The silty sediments hold larger amounts of water and as a consequence are colder than coarser sediment. Fine-grained sediments do not raise the ground level to the same extent as coarser sediments, which also increases the vegetational differences between the subzones. Silty sediment compacts more and slower than sandy sediments, which also causes differences in the development of the vegetation in the different subzones.

Two different zone borders can be distinguished between the willow vegetation and the swamp vegetation, which are differently distributed in relation to the streaming water and exposure (see Fig. 34). Either (1) the frequency and height of the willow shrubs decrease in the swamp getting closer to the lagoon or (2) the boundary is very sharp. This is illustrated in belt-transect 22 in Fig. 22 and in belt-transect 23 in Fig. 25.

(1) A gradual border is found when the slope is very gentle, e.g. in the western upstream part of the interlevee basins or inside concave bends where at flood the water is spread over large areas (see section 8.2 and Fig. 87). As the frequency and height of shrubs decrease, the outermost ones can frequently hardly be seen above the swamp vegetation. The snow cover is sufficient and the shrubs are totally covered, which saves them from moose-browsing during most of the winter, since moose do not dig in the snow for food.

In the early phases of the willow succession the vegetation usually consists of two or three layers but as the willows close up only one layer remains viz. the shrub layer. The willows in the swamp are usually low and growing separately even where the vegetation is old. The vegetation types found in closed lagoons in the interjacent subzone and the subzones close to the levee crest are treated together in section 4.5.4 since there is usually a continuous development and the different vegetation types can appear anywhere along the gradient although with differences in time in the same lagoon.

(2) The boundary is very sharp where there is a comparatively steep slope from the levee crest towards the lagoon. Usually this kind of willow border is found along narrow levees, either along active distributaries or upstream from active or abandoned ones, where loading is less than downstream (see Figs. 4 and 87). The surface of the shrub layer usually reaches about the same upper level, but since the ground slopes they are in fact slightly higher the closer to the swamp they grow. This is most pronounced in extreme westerly exposure where the shoots protruding above the snow are killed in winter. Drifting icy snow particles wear off the bark only on one side of the shoots, while moose-browsing removes the whole shoot, or the moose may scrape off the bark all around. Gill (1973a p. 149) noticed that "moose are browsing animals, particularly in winter, and depend on early successional shrub for most of their food". Swedish moose are also known to prefer willows to most other woody species, especially in winter and near streams.

Group VII. With increased water depth *Calliergon giganteum* becomes mixed with *Drepanocladus trichophyllus*.

Group VIII. *Carex rostrata* reedswamp (4.4.1.4). *C. rostrata* and *Equisetum fluviatile* dominate in the deepest parts of the water-covered area. In places there are dead clumps of sedges on the bottom. In 1904 this area was covered by swamp vegetation.

Group IX. *Carex aquatilis* dominates and *Equisetum fluviatile* is frequent. Towards the levee ridge *Carex aquatilis* becomes frequent in the sedge reedswamp on sod (4.4.1.2). There is a narrow area of mixed sedge swamp on sod (4.4.2.2) bordering the levee.

Group X. Dead or dying birch or willow vegetation with a mixture of terrestrial and telmatic species (4.5.4.4, CX). *Carex rostrata* and *Equisetum fluviatile* codominate and are most frequent. The more terrestrial species found always grow in comparatively high moss tussocks (generally *Polytrichum commune)* or on the roots and stems of willows or birches. *Equisetum fluviatile* invades rapidly in more wet areas.

Group XI. *Carex rostrata* reedswamp (4.4.1.4) and mixed sedge swamp on a sod (4.4.2.1).

Group XII. *Carex aquatilis* occurs but with increasing depth *C. rostrata* will become the only species left.

4.5.1. Swamp-willow subzone

4.5.1.1. Scattered willow shrubs in mixed graminid swamp

The willows can be very low, not reaching above the level of the swamp field-layer species, or up to three metres high. Usually they grow quite apart with a mixed graminid swamp vegetation in between (see Fig. 19). Underneath the shrubs there is hardly ever any field- or bottom-layer vegetation. The sod of the swamp may be very thick (see Table 3, plots 10 and 15).

4.5.1.2. Scattered willow shrubs in moss-covered swamp

The willow shrubs are usually at least 2 m high as this kind of vegetation is found at a higher level than the previous type, and might possibly also be older. The moss cover is usually dominated by swamp mosses (see Table 3 plot 9).

4.5.1.3. Closed willow shrub vegetation initiated in swamp vegetation

This kind of vegetation could either form the border directly towards the swamp zone or could be bounded towards the lagoon by either scattered willow shrubs in mixed graminid swamp (4.5.1.1) or scattered willow shrubs in moss-covered swamp (4.5.1.2). The field vegetation is often sparse, but scattered specimens of *Carex aquatilis, Equisetum fluviatile, E. palustre, E. arvense, Epilobium palustre* and tussocks of *Carex juncella* frequently grow together with species enduring a fairly high water content in the ground. A bottom layer is frequently missing but scattered moss specimens living on the stems and roots of the willows can be seen, particularly *Dichelyma falcata* and *Calliergon cordifolium*. The very abundant litter fall and the density of the shrub layer are the main causes excluding all bottom or field layer (see transect 22 in Fig. 22 and belt-transect 38 in Fig. 20).

The vegetation types mentioned in 4.5.1.1, 4.5.1.2 and 4.5.1.3 are found in young lagoons or in bays with the same water-level fluctuations as the distributaries or in lagoons with a low low-water threshold.

4.5.1.4. Scattered dead or dying willows in mixed sedge swamp

In lagoons with raised water-level there are often dead or dying willows in the swamp vegetation. The sod in these areas is of various thickness. The shrubs are surrounded by swamp vegetation growing slightly higher than the rest of the swamp vegetation and acting as refuges for less flood-tolerant species than those found in the ordinary swamp vegetation. After the shrubs die, swamp vegetation soon covers the shrubs.

4.5.1.5. Deteriorated closed shrub vegetation initiated in swamp vegetation

Usually the shrub layer was never found to be as dense as in the interjacent subzone. After a decrease of the vitality of the shrubs, swamp vegetation invades on top of the roots and stems (see belt-transect 33 in Fig. 33). Dead or half dead willow specimens evidently emanating from former growth in the swamp subzone have been seen on the bottom of lagoons. This kind of willow vegetation is found along the shores of old lagoons with a raised water-level both during the summer and the autumn.

4.5.2. Interjacent subzone willow vegetation

4.5.2.1. Low willow pioneer vegetation

The willow shrubs in this kind of pioneer vegetation are around 0.5 m high and the field layer is mostly poor in species, with *Carex aquatilis* constantly appearing. Terrestrial species also occur. This kind of vegetation frequently becomes covered by sediments from a distributary, burying the bottom layer. The pioneer vegetation covers large areas, e.g. at the delta front, and then with increasing age is differentiated due to its position in relation to distributaries and lagoons (see Table 5, plot 4; transect 12). It is regarded as a part of the progressive succession.

4.5.2.2. Tall willow vegetation with mainly telmatic species in the field layer

The willow vegetation with telmatic species may have developed from swamp or pioneer vegetation and characterizes the lower part of the zonation. There are only scattered specimens of telmatic species to be found, such as *Carex aquatilis, Equisetum palustre, E. fluviatile* and a few others. The ground is usually made up of roots and stems of the willow shrubs and is covered by willow litter (see belt-transect 21 in Fig. 26; belt-transect 23 in Fig. 25).

4.5.2.3. Tall willow vegetation with a mixture of telmatic and terrestrial species in the field layer

In the higher parts of the interjacent subzone a few terrestrial species mix with the sedges, e.g. *Rubus*

arcticus, Trientalis europaea, Pyrola minor. Festuca ovina and *Pedicularis sceptrum-carolinum* appear frequently (see belt-transect 22 in Fig. 22 and belt-transect 23 in Fig. 25).

The willow vegetation described in 4.5.2.2 and 4.5.2.3 is found in open lagoons where the low-water threshold is slowly rising. They may also be different successional stages as a consequence of drier conditions; tall willow vegetation with telmatic species may develop into tall willow vegetation with a mixture of telmatic and terrestrial species whereas, under wetter conditions, the reverse may occur.

4.5.3. Willow vegetation subzone close to the levee crest

4.5.3.1. Low willow pioneer vegetation with scattered birches

In this part of the zonation scattered birches (in the shrub layer) are commonly found. There is usually a mixture between pioneer species, swamp species and terrestrial species. Flooding is quite frequent but the ground is mostly covered by mosses which in turn, however, frequently become buried. Lichens, especially *Peltigera* spp., probably play an important role as nitrogen fixers (Kallio 1978, Milbank 1978 among others).

Low willow pioneer vegetation with scattered birches covers large areas at the delta front and at point bars along the distributaries (see Table 5: plot 5 and 16 and belt-transect 4, squares 30–34).

4.5.3.2. Tall willow vegetation with a field layer dominated by terrestrial species

In the upper part of the zonation there are only terrestrial species scattered among the very densely growing willows. The vitality of the shrubs, which may be very tall, 2–4 m, is usually of degree 3, but might locally become reduced to 2 due to drought or age (see belt-transect 23 in Fig. 25). This willow vegetation is found along shores of all open lagoons. It can also be recorded in closed lagoons with a raised low water-level, where it eventually becomes invaded by swamp species.

All willow vegetation close to the levee crest has probably started as a xerach pioneer vegetation dominated by *Calamagrostis neglecta*.

4.5.4. Vegetation types in the interjacent and leveeward willow subzones of closed lagoons, retrogressive succession

The vegetation types outlined below might be different stages in the same retrogressive succession or also initial stages of different retrogressive successions, depending on the original vegetation, the composition of the soil, the rate of the rise of the relative water-level and of the ground-lowering processes, if any. The vegetation types are characterized with regard to the field and bottom layer and also to the structure of the soil. The vitality of the shrubs in this vegetation is generally of degree 0–2.

4.5.4.1. Deteriorated willow vegetation dominated by mosses in the bottom layer

In the progressive succession the areas covered by a very dense shrub layer very often have a poorly developed field and bottom layer and the ground is frequently covered by a 30–40 cm thick layer of roots and stems of *Salix* shrubs. In the retrogressive stage, on the other hand, the shrubs die and the lower vegetation layers may develop along different lines. There are two common vegetation types found in areas which were formerly covered by dense willow vegetation: one has the ground covered by a thick moss carpet, the other (4.5.4.2) has a field layer dominated by sedges. The moss carpet could emanate from an already existing moss cover or could be a result of an invasion of mosses following a moderate rise in the relative water-level and a moderate reduction in the cover of the willow scrub. Scattered or solitary specimens of *Carex aquatilis, C. rostrata, C. canescens* and *Eriophorum angustifolium* together with a few other species are frequently found rooted in the moss cover. *Epilobium palustre* often grows on the stems and roots above ground level (see for example belt-transect 33, groups II and III in Fig. 33).

4.5.4.2. Deteriorated willow vegetation dominated by sedges in the field layer

The sedge vegetation is characterized by an invasion of swamp species and the development of a sod on top of the root-and-stem covered ground. Different stages of this vegetation are found in several places, ranging from a stage where the vitality of the willows is of degree 2 and the cover of swamp species 50–80 %, to stages with only white sticks of *Salix* left in a mixed sedge swamp on a 20 cm thick sod on top of the root and stems of the willows (see e.g. belt-transect 33 group IV in Fig. 33; belt-transect 23 in Fig. 25).

Fig. 35. Dead willow vegetation in open water as remnant of an earlier willow vegetation now drowned in lagoon 37.

4.5.4.3. Willow vegetation where open water covers the ground most of the year

The willow vegetation growing in frequently inundated conditions is most frequently found quite close to the levee. Water depths between 20 and 50 cm have been recorded (see Fig. 35). The shrub-layer is usually dense, although with a reduced cover through the dying-off of the shrubs. There are mainly two different species combinations. In water deeper than about 40 cm there is frequently a kind of vegetation characterized by scattered specimens of *Carex aquatilis, C. rostrata* and *Equisetum fluviatile,* but also other swamp species may appear (see belt-transect 11 in Fig. 30). In water shallower than about 40 cm a combination of *Hippuris vulgaris* and *Calamagrostis purpurea* is frequently found. *Potentilla palustris* and *Petasites frigidus* also appear together with scattered sedges (see belt-transect 21 in Fig. 26; Fig. 36). These vegetation types can either develop into areas of open water with or without sparse vegetation but always with dead sticks of *Salix,* or into swamp vegetation.

4.5.4.4. Dead or dying birch or willow vegetation with a mixture of terrestrial and telmatic species in the field layer

Vegetation of this kind is characteristic for low levee ridges and meander scrolls in closed basins. The levee ridges were formed by small channels or distributaries that were early abandoned and the low meander scrolls were quickly cut off from distributary contact by another point bar. These ridges and scrolls sometimes become covered by a row of birches but are more frequently covered by willow shrubs. They are usually overgrown by swamp vegetation frequently dominated by *Eriophorum angustifolium* (see Fig. 32). In several places the ground is covered by mosses, of which *Polytrichum commune* may form up to 1 m^2 large mats, thus somewhat raising the ground surface creating refuges for terrestrial species.

The birch vegetation along active distributaries (distributaries directed in the stream direction) surrounding closed lagoons is rarely drowned, partly because of the frequently very long distance to the lagoon, and partly because of the frequent flooding with deposition of sediments. All dying birch vegetation is found along channel levees, distributary levees or meander scrolls situated inside closed interlevee basins. Since the vegetation along channels to open lagoons is the same as along active distributaries the retrogressive vegetation types recorded along levee ridges and meander scrolls in closed lagoons could be presumed to be a retrogressive stage of this vegetation.

4.6. Progressive and retrogressive succession

A description is given in the introduction of such vegetational characteristics that can be used as criteria in deciding whether the succession is progressive or retrogressive. In general, the vegetation found in open lagoons is regarded as belonging to the progressive succession and the types found in closed lagoons to the retrogressive succession.

In the delta the progressive hydrarch succession, starting with *Eleocharis acicularis – Subularia aquatica* vegetation, passes with a reduced diversity, although with an increased biomass, into the *Carex aquatilis*' vegetation. The driving force for this development could be the rising of the bottom due to sedimentation. The increase in diversity from the single species community of *Carex aquatilis* to the mixed graminid swamp is also progressive. This succession is caused by a rise in land level, either by a

Fig. 36. Dead and dying willows; field layer with *Hippuris vulgaris* and *Calamagrostis purpurea*. Water depth around 20 cm. From belt-transect 21 in lagoon 51.

growth in thickness of the sod or by sedimentation or, most probably, by a combination of both. The development of willow shrubs is regarded as progressive, partly due to the larger biomass and partly because willow-shrub vegetation according to some criteria could be classified as a more stable vegetation type than swamp vegetation. However, Horn (1974) gives reasons for an opposite opinion, viz. that climax communities are more vulnerable than early stages.

In deciding whether a succession is to be regarded as retrogressive, different criteria are also used. The death of willow shrubs involves a transition to a less stable community and also a decrease in (living) biomass, although sometimes the diversity may increase. The change from swamp vegetation to open water without vegetation is evidently retrogressive by all criteria. Fig. 88 shows schematically the most important steps in the succession and also some of the processes involved in this development.

The most important factor governing the progressive or retrogressive character of a succession is the change in the relative position of the water-level in relation to the ground level (Nichols 1923: topographical succession). However, the water-level is always variable, but not equally over all the delta.

The willow succession has been divided in three different parts which seldom mix. The swamp-willow subzone (Table 3), the interjacent willow subzone (Table 4) and the willow subzone close to the levee crest (Table 5). These tables are based on subjectively linked vegetation analyses. The small square frequency is the number of squares in which the species occur calculated in per cent of the total number of squares in parts of belt-transects and in parts of plots (the ten squares along each side of the plot). The characteristic cover (Malmer 1962) has been calculated for the same squares. The analyses have been linked by appraisals based on the vegetation analyses, by the surrounding vegetation, the position of the square, the soil, the hydrology of the interlevee basin and the age of the area in question. The succession between the different parts is only occasionally truly verified by repeated square analyses (AI–AII and BI–BII) but in some cases, e.g. the disappearance of willow vegetation, proof of the succession can be said to be obtained from photographical evidence. (See pp. 103–110.)

5. Description of six lagoons, their vegetation, hydrology and development from 1899 or 1904 to 1974

5.1. Methods

5.1.1. Hydrology of the interlevee basins

The water-level has been read visually on scales fitted to wooden panels placed in the lagoons (see Fig. 4). The gauges were levelled repeatedly in relation to fixpoints in the delta level chain, in order to detect any movements of the gauges. Recorded movements have been regarded in plotting the water-level variations. For the measuring periods see section 2.4.1.

On July 18 the highest water of 1973 began. This extreme high water drowned the whole delta area apart from dune landscapes and quite large parts close to the delta front. The whole interlevee basins were mostly water-filled when maximum water discharge was reached. The highest water-level in the delta persisted between 2300 on the 18th and 0300 in the morning of the 19th. During this time the level of the water was marked by means of sticks put down on the levees at the water-level. Their heights were then levelled. These measurements were supplemented by observations of the highest water-level shown by sedimentation lines on the ground and on the vegetation. However, the absolute maximum water-level is known with certainty only at water-level gauge No. 7, where observations were made during the whole night.

The water-level measurements in the lagoons are given in relation to water-level gauges in the Kuoutätno. The duration of different water-levels as shown in connection with the vegetation transects has been calculated from the water-level diagrams.

The water-level durations (transect 21) in lagoon 51 and in lagoon 105 (transect 33) were measured in the lagoons. For lagoon 92 (transect 22) and for lagoon 80 (transect 38) the duration at Kuoutätno No. 1 has been used. The water-level variation in lagoon 62 (transect 23) has been estimated from the values of the water-level variation in lagoon 60 together with one late autumn observation (1973) in lagoon 62.

The efficiency of the lagoon channels is of great importance for the lowering and rising of the water-level in the lagoons. Observations in the lagoon channels have been made at different water-stages and at different times of the year. In a few channels (e.g. those leading to lagoon 105, see Fig. 64, and lagoon 36) the bottoms and levee crests have been levelled with reference to the water-level in the lagoon and the distributary passing by.

The water-level in the channel leading to lagoon 36 and the bottom of it close to the distributary was far below the water-level in the lagoon, but at the connection of the channel and the lagoon the bottom was at the same level as the water-level in the lagoon. Thus the threshold is situated at the lagoon-channel junction. In lagoon 105 the bottom of the channel at the lagoon-channel junction was below the water-level in lagoon 105 (cf. also Fig. 12 and Fig. 64). At high water, areas of low ground around the lagoons are easily detected, and at low water thresholds are very marked.

5.1.2. Interpretation of photos and the development of prominent features in the delta

A fairly large number of photos of the delta area were taken by Professor Hamberg who worked in the Sarek mountains for over 30 years during the early part of this century. They were taken from the surrounding mountains (Skerfe, Tjakkeli and Nammatj) between 1899 and 1922. Together with air-photos taken in 1954, 1962, 1963, 1965/66 and my own photos from 1970–1974 they enable the development of the delta to be studied.

The photos from the surrounding mountains are oblique, which makes it complicated to make any measurements on them. In the present paper Hamberg's photos have only been used to reveal major geomorphological and vegetational differences between 1899 and 1974. In a few cases the year of the photo is not known but the approximate time could be estimated by comparison with other photos.

The interpretation of the development is given in

maps covering the specially studied lagoons. The most important factors which could influence the interpretation of the water regime and vegetation in the lagoons are: (1) the photographic angle, (2) the water discharge at the time of photographing, (3) the time of the year when the photo was taken.

These factors are relevant for the air-photos and for the photos I have taken myself. Furthermore, I have been able to check the actual water-level conditions. In some cases the interpretation of the old photos was difficult.

5.1.2.1. The photographic angle

By comparing photos taken from the same direction, e.g. from the same mountain, the distortion can to a certain degree be neglected when comparisons are made of forms and extensions of different objects. Photos taken on the same occasion from all three possible directions (south, west and north) are available and by comparing them it is possible to discover the more important distortions. The southeastern part of the delta is not well represented on the early photos. From Mt. Tjakkeli these areas are usually not reproduced due to the steepness of the mountain and from Mt. Skerfe the angle becomes too low for any good interpretation. The photographic angle has its main influence when interpretations are made in the following three respects.

The form and the size of the lagoons: The form of a lagoon becomes very distorted when seen at a low angle. The problem of identification could almost always be solved with the help of surrounding morphological features, especially islands of till, and by comparison with the form of the lagoon today. The exact difference in the size of the lagoon is impossible to determine but it is often possible to say whether the water area was larger or smaller in 1899 than in 1974.

The width of the channels, especially those meandering inside the lagoons: Errors in this respect are very important because the classification of the water regime in the lagoons depends on the function of the channels. Comparisons of photos taken from different directions reveal the actual possibility as to the functioning of the channels. Usually it is possible to decide whether a channel has an active contact with the lagoon but when *Carex* swamps have filled up the area between the water and the end of the channel misinterpretations may well be made. Channels passing through woodland are often impossible to see on an oblique photo.

The extension of different vegetation types: The possibility to distinguish different kinds of vegetation types and the border between them varies greatly depending on the variation in quality of the early photos, but usually it is possible to distinguish between birch woodland, willow shrubland and swamp. The border between the reed-swamps and the water is almost always easy to observe, although it is, of course influenced by water-level and season, but the real extent of the swamp zone could be diminished by *Salix* shrubs at a low photographic angle. On young land there is usually no distinct border between areas dominated by birches and *Salix* shrub vegetation but the trees are easy to see. On older land the same problem will arise as between *Salix* shrubs and swamps, since the birches hide the border. In some cases shadows from the vegetation can enlarge the visual impression of a certain vegetation type.

5.1.2.2. Influence of the water discharge on photo interpretation

The water discharge at the time of photographing is very important for the interpretation. The water-level in Lake Laitaure is not known for the time of Prof. Hamberg's early photos. The water discharge at Litnok is only known for 1922. However, depending on the amount of sandbars visible in the distributaries and the amount of boulders seen above the water surface it is possible to tell whether it is high or low water. Differences in water discharge have importance for the interpretation of the development of both geomorphological features and the vegetation.

Size and form of the lagoons: At high water the size of old lagoons is usually not much enlarged but in young lagoons with indistinct borders between the open water and the swamp vegetation the high water may drown the vegetation more or less completely, the interpretation then giving the open lagoon too large a size.

Interpretation on photos taken at low water probably becomes fairly exact. The border between a dried-out lagoon bottom and adjacent swamp vegetation appears sharp, and in lagoons with relatively small water-level fluctuations the lowering of the water-level makes the boundary still more distinct due to sedimentation on the *Carex* leaves when the water-level sinks. However, the lagoon area might look smaller than it actually is.

The function of the channels: As pointed out earlier, the thresholds are usually situated at the lagoon-channel junction. In places where a miniature delta is building up existing thresholds are easily seen on low-water photos whereas they are drowned on high-water photos. When the connection is occupied by swamp vegetation a threshold must be presumed but its height and influence on the water-level in the lagoon

cannot be determined. Almost all channels are filled with turbid water from the distributary even at relatively moderate high water, but this does not reveal whether there is a low-water threshold or not.

5.1.2.3. Influence of season on photo interpretation

The air-photos were taken just before the vegetation period started, and all other photos were taken at different times during the vegetation period. The differences during the course of the vegetation period are not too complicated since the swamp vegetation is marked by its abundant standing litter even before it grows out in full. It is likely that photos taken in the autumn would provide the best contrast.

5.2. The lagoons

Six different lagoons have been chosen for close study, in accordance with their different hydrology and vegetation. A description is given of their hydrology, recent vegetation and the development of the vegetation and land as interpreted from the old photos. The different vegetational units used have been characterized in chapter 4, as well as the methods used.

5.2.1. Lagoon 69

The description also includes lagoons 61 and 62 situated in the same interlevee basin. For location see Fig. 4.

Lagoon 69 is the largest of those entirely inside the delta, i.e. without any above-ground connection to till deposits or to land. The lagoon is bordered by well-developed levees to the north and south. To the west the border lies in the swamps between lagoon 69 and lagoons 61 and 62. To the east the lagoon borders are under development in the form of sparsely vegetation-covered bars and swamps. Together with lagoons 92 and 75 (see Fig. 4), this is the shallowest lagoon in the delta, and can be crossed in waders at mean water-level.

In 1904 this lagoon constituted a bay of Lake Laitaure (see Fig. 38) and had probably been so for hundreds of years. Like the present lagoon 69, the former bay was situated between the two main distributaries Kuoutätno and Nuourtätno which split about 4 km west of the distal part of the present lagoon. The area between the lagoon and the bifurcation point consists of swamps, lagoons and one birch-covered levee passing across this interlevee basin (see Fig. 4). The lagoon is very large due to the divergent direction of the main distributaries. The bay became wider until the bay-bordering levees reached the position they had in around 1904, when the levees started to curve towards each other, which initiated the formation of a lagoon from the open bay (see Figs. 38, 39: areas B and

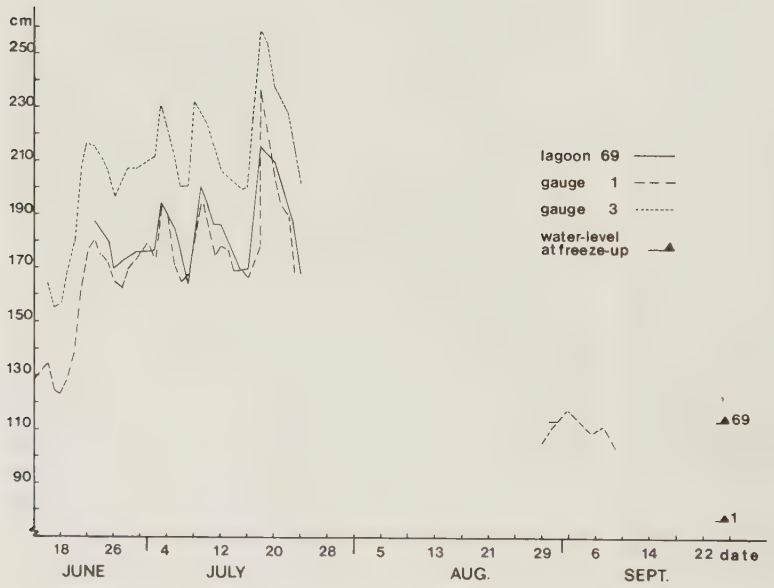


Fig. 37. Daily water-level variation in 1973 in lagoon 69 compared with that of Kuoutätno 1 and 3 and the water-levels at freeze-up in the lagoons. 150 cm is equivalent to 494.8 m above M.S.L.

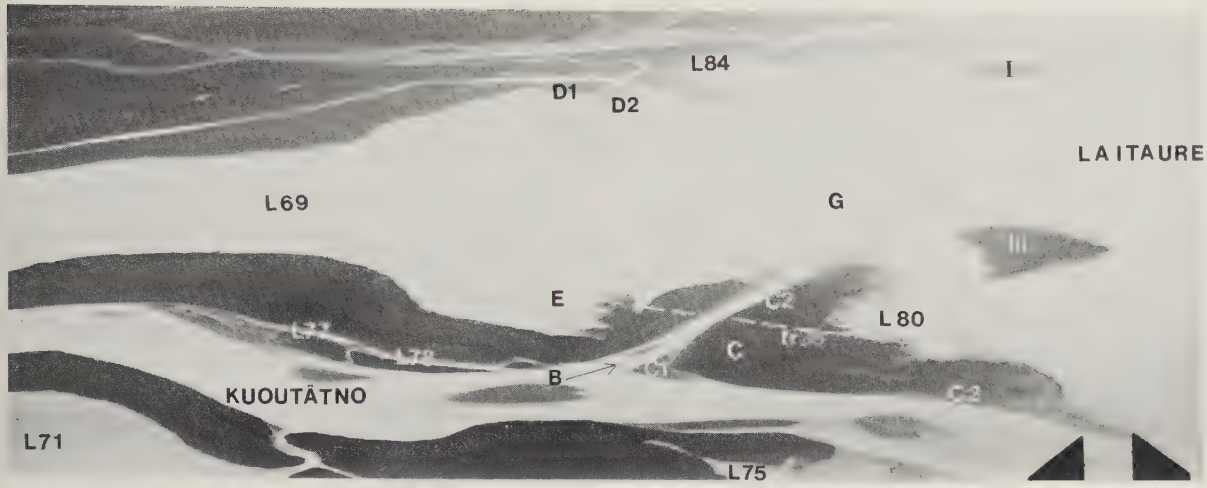


Fig. 38. The delta front with lagoon 69 (L69) from the south (Tjakkeli) in 1904. At that time Lagoon 69 was a bay of Lake Laitaure but the lagoon formation had started by the formation of bar C and by the curving of the River Nuourtätno in areas D1 and D2. The position of belt-transect 38 (tr. 38) is marked. Relatively low water-level. Areas discussed in the text are marked with letters and Roman numerals (L=lagoon). Till islands (including former islands now enclosed in delta sediments) are marked with Roman numerals. For explanation of the markings see section 5.2.1.3 (lagoon 69).

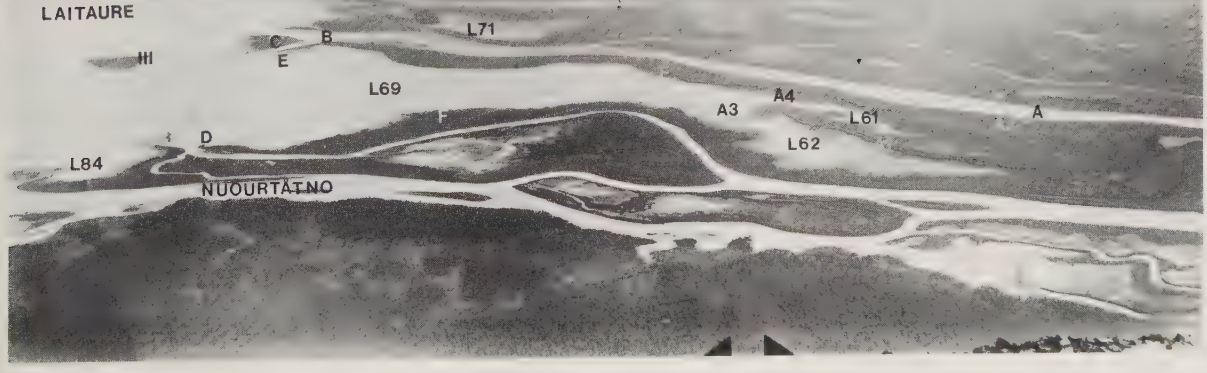


Fig. 39. The delta front and lagoons 69, 61 and 62 from the north (Skerfe) in 1904. The water-level was higher than in Fig. 38 and the bar D2 cannot be detected. The distributary A was open and carried turbid water to area A3. For explanation of the markings see section 5.2.1.3 (lagoon 69).

D). This was probably due to the influence of the till islands I and III (Fig. 4). The scarcity of till islands in this area is probably another reason for the large size of the lagoon. Where till islands are abundant the lagoons are numerous but small; compare the area south of the Kuoutätno (see also Raup 1934). The depth of the original basin in the area must have influenced the time needed for the closure of the bay.

As the two main distributaries bordering the lagoon carry large amounts of water and as the energy gradient is smallest in the stream direction, only few new permanent distributaries or channels have been formed. Sandbars formed in the Kuoutätno are rarely persistent. However, four partitions can be seen along the Kuoutätno (see Fig. 4).

5.2.1.1. Hydrology

A channel connects lagoon 69 with the active delta distributary Nuourtätno, and another with Lake Laitaure. Fig. 37 shows the water-level variation in the lagoon and at water-level gauges Nos. 1 and 3. The water-level variation in the lagoon corresponds to water-level gauge No. 1 almost perfectly. Water-level measurements at gauge No. 3 have the same general appearance as those at No. 1 but lie about 40 cm above lagoon level. The water-level variations follow Lake Laitaure except for extreme high water and extreme low water. The high water on July 18 did not pass over the levees to the lagoon—at least not along the Kuoutätno—and the rising water-level in Lake Laitaure did not reach as far backwards as the water-level gauge in the lagoon. This means that for a few hours the water-level in lagoon 69 at the gauge was lower than the water-level at gauge No. 1 at the delta front.

There are no low-water thresholds in the outflows and consequently the larger part of the lagoon bottom is exposed at low-water. An air-photo from 1954 (Fig. 16) shows this, when Lake Laitaure was at 100 cm (compare also Fig. 17).

At freeze-up the lagoon is either empty or has very little water left and in 1973 the water-level at gauge No. 1 was about 30 cm below the lagoon bottom at the site of the lagoon gauge. The maximum water-level amplitude amounts to about 100 cm.

5.2.1.2. Vegetation in and around the lagoon in 1974

The swamp and willow zones are well developed and the vegetation is healthy. The levee crests are covered by birches. The larger part of the lagoon bottom is covered by vegetation, the deepest parts and the outflows excepted.

Open water vegetation: In the eastern part *Eleocharis acicularis – Subularia aquatica* vegetation could be found in sheltered bays. In the western part *Potamogeton alpinus – Sparganium* sp. vegetation is found.

Swamp vegetation: The reedswamp around the lagoon is dominated by *Carex aquatilis* without a sod, but *Carex aquatilis* is sometimes replaced by *Equisetum fluviatile* as, for example, in areas between the lagoon and lagoons 61 and 62 where *Equisetum fluviatile* dominates the former passage. In parts exposed to the west an erosion notch, 1–2 dm high, has developed. The sediments are clearly kept together by the *Carex* roots and rhizomes.

The interjacent swamp subzone is covered by a mixed sedge swamp on sod. A sod up to 30 cm in thickness is developed, which is thicker in the western part of the basin than in the same subzone in the eastern part. Its thickness also diminishes towards the open water along all shores. The interjacent swamp in lagoon 62 is a floating mixed sedge swamp. The shoreward part of the swamp zone in the same lagoon has developed to a mixed graminid swamp but in exposed positions the swamp is often litter-covered. Where the levee is narrow and steep the shoreward swamp is often covered by a moss carpet.

Willow vegetation: The willow shrubs are healthy and vital all around the lagoon except on the northern side of lagoon 62 where the vitality of the shrubs is low locally. In the western part the willow zone is very old and the highest shrubs in the delta grow there, being around 4 metres. The willow shrublands are younger the further to the east they are situated.

5.2.1.3. The delimitation of lagoon 69 and the development of vegetation from 1904 to 1974

Most of the new land (see Fig. 42) has been built up in the eastern part. In the western part the connections to lagoons 61 and 62 have been colonized by vegetation. Along the northern and southern shores the swamp and willow vegetation may have expanded towards the lagoon but the extent of the zones could have been stable during these 70 years (see Fig. 43). For location of the different areas described see Figs. 38, 39, 40 and 41.

Area A: At this point the Kuoutätno once split forming a distributary, the levees of which divided the basin into lagoons 61 and 62.

In 1904 the entrance to the distributary was open, but a sandbar at the inflow might have formed a low-water threshold. In 1922 this sandbar had grown but

Fig. 40. Lagoons 69, 61 and 62 from the north (Skerfe) in 1922. Relatively low water-level. Note especially the development of areas C2 and D3. Area A3 has hardly changed between 1922 and 1974. The water course has, however, been overgrown by vegetation. For explanation of the markings see section 5.2.1.3 (lagoon 69).

Fig. 41. Lagoons 69, 61 and 62 from the north (Skerfe) in 25 July 1974. Water-level in Lake Laitaure=152 cm. The position of belt-transect 23 (tr 23) is shown. The distributary between lagoons 61 and 69 is overgrown by *Equisetum fluviatile*. Note also the development of area D3, and the bar C behind which lagoon 80 (erroneously marked L83) has been enclosed. For explanation of the markings see section 5.2.1.3 (lagoon 69).

water was probably still entering the distributary as there was growth of land at the other end of it (area A3). In 1974 the distributary was completely closed. Water can hardly pass the threshold even at extreme high water; however, the deepest parts are water-filled.

Area A1. Constitutes the levees formed along the distributary. In 1904 the levees were covered by willow shrubs except for the eastern part where pioneer vegetation surrounded the channel depression. A few birches were detectable on the levees in the part of the distributary close to the Kuoutätno. In 1922 the levees were covered by willow shrubs to the same extent as today. A few birches could be seen along the levees. The pioneer vegetation had developed into swamp vegetation. In 1974 birches had developed along the whole length of the levee pair. The willow zone is narrow and rather steeply inclined and the swamp vegetation often extends into the willow zone.

Area A2. In 1904 this area was covered by willow vegetation. There was, however, a border between the willow close to the distributary and the willow shrubland closer to the lagoon. In 1922 the willow shrubs had expanded out into the swamp and single birches had developed in the area close to the distributary. In 1974 a zone, 100 to 150 m broad, along the distributary is covered by birches with a comparatively dense shrub

Fig. 42. Land development around lagoon 69 from 1904 to 1974. 1. Open water in 1974; 2. Areas covered by vegetation which were found to be permanent from 1904 to 1974; 3. Pioneer vegetation-covered sand bars in 1904; 4. Areas not visible or bars or mudflats without vegetation in 1904 but visible or with vegetation in 1922; 5. Land formed between 1922 and 1954; 6. Land formed between 1954 and 1974; 7. Sand bars visible in 1954 but not in 1974; 8. Vegetation-free bars in 1974; 9. Till; 10. Border between swamp vegetation and willow or birch-covered land in 1954 (see Fig. 43, no. 18); 11. Border between sand bars and open water in 1954; 12. Direction of current. Solid lines in equally marked areas stand for vegetational differences in 1954, mainly the border between swamp and willow covered areas.

layer. *Salix* shrubs in the area east of the birchwood are between 3 and 5 m high and there is no field layer. The willow zone extends into the swamp by means of low shrubs. There were no signs of heavy overbank deposition due to levee erosion. The bar island now situated in the middle of the distributary was earlier connected to the northern shore, thus protecting the levee from erosion. Today the levee is eroded as the deep pool of the distributary is situated north of the bar (Fig. 16).

Area A3: Comprises the connection between the distributary A and the water area of the interlevee basin and the border between the lagoons 69 and 62. In 1904 there was an open passage between the two lagoons. In 1922 the expansion of the swamp and the formation of new bars (turbid water carried by distributary A) had delimited the connection to a channel. In 1974 the channel is only distinguishable as a strip with sparsely growing *Carex aquatilis*.

Area A4: Connection between lagoons 61 and 69. In 1904 there was a rather broad passage between the lagoons. In 1922 the development of land and vegetation had made the connection narrower. In 1974 the whole passage is overgrown by *Equisetum fluviatile*.

Area B: The first splitting of the Kuoutätno downstream area A. In 1904, on a photo taken at low water, the distributary can be seen to be comparatively broad but sandbars had formed in it. A point bar, C1 upstream of C had also developed. In this year no bars were seen in the distributary but C1 persisted. In 1922 a bar had been formed at the inlet of the distributary which extended both upstream and downstream along

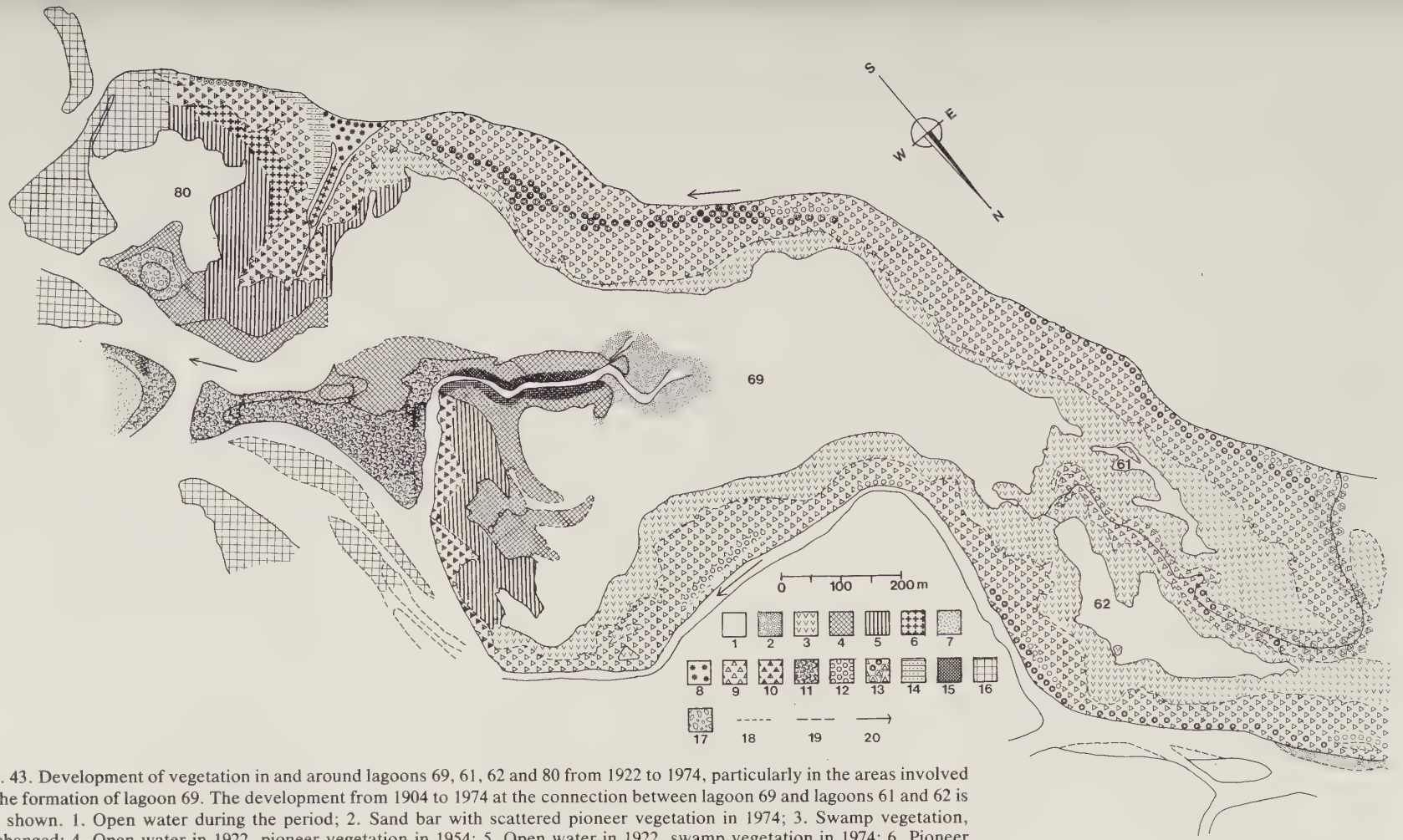


Fig. 43. Development of vegetation in and around lagoons 69, 61, 62 and 80 from 1922 to 1974, particularly in the areas involved in the formation of lagoon 69. The development from 1904 to 1974 at the connection between lagoon 69 and lagoons 61 and 62 is not shown. 1. Open water during the period; 2. Sand bar with scattered pioneer vegetation in 1974; 3. Swamp vegetation, unchanged; 4. Open water in 1922, pioneer vegetation in 1954; 5. Open water in 1922, swamp vegetation in 1974; 6. Pioneer vegetation in 1922, swamp vegetation in 1974; 7. Open water in 1954, swamp vegetation 1974; 8. Poorly vegetation-covered bars in 1922, in 1974 covered by willow and birch scrub; 9. Willow shrub vegetation with unchanged good vitality; 10. Establishment of willow shrub vegetation from 1922 to 1974, high willow vegetation; 11. Establishment of low (0.5 m) willow vegetation from 1922 to 1974, either from open water or from pioneer vegetation-covered bars; 12. Unchanged occurrence of birch; 13. Birch-establishment in willow dominated vegetation from 1922 to 1974; 14. Birch vegetation in areas influenced by wind-blown sediments; 15. Levee ridge with xerarch pioneer vegetation (willow seedlings); 16. Land with different kinds of vegetation, development not shown; 17. Till; 18. Border between swamp vegetation and willow or birch-covered land in 1954; 19. Border between sand bars and open water in 1954; 20. Direction of current. Solid line in areas with equal marking see Fig. 42.

the Kuoutätno. However, the distributary still had connection with the Kuoutätno. A large part of distributary B was filled with sandbars. In 1974 the sandbar closing distributary B had grown so high that even the extreme high water of 1973 was hardly able to pass it. This is partly due to the influence of wind-transported sediments. The vegetation along the former distributary between the levee crests follows a gradient from a dry vegetation type where low willow shrubs and 1–1.5 m high young birches dominate in the southern part close to the distributary, to a swamp with scattered high willows in the northeastern part. The former pools of the distributary are today small lagoons, often situated along the levee crests. The deepest of them have a minerogenous bottom while the bottoms of the shallower ones are covered by a moss-carpet (of mainly *Drepanocladus uncinatus, Hypnum lindbergii* and *Bryum pseudotriquetrum).*

Area C: The distributary-mouth bar forming the eastern limit of distributary B. In 1904 this bar was probably only covered by pioneer vegetation. It is impossible to detect whether there were any willow shrubs or not. In 1922 the central part of the bar was covered by willow shrubs and the sides of the bar had extended further downstream. In 1974 birches have developed on the levee crests along the Kuoutätno and distributary B approximately to point C2 (this young birch-covered area is highly influenced by wind-blown sand). Between the levee crest and lagoon 80 there is a 100–150 m broad comparatively dry willow vegetation, the shrubs being between 2 and 3 m high. The levee pair (see transect 38 in Fig. 21) are equally high but birches have only developed along the eastern one, which is mainly built up of wind-blown well-sorted sandy sediments.

Area E: Constitutes the levee and adjoining areas upstream of distributary B. In 1904 this area was covered by pioneer vegetation except on the levee crest where willow shrubs had developed. Compared with area B downstream this part was about 1/4 in breadth. In 1922 the breadth of the area did not seem to have enlarged but the levee had become longer. In 1974 there are only solitary birches in this area. The levee vegetation is dominated by 2–3 m high willows. In the field and lower shrub layers there are, however, species normally growing in birch-dominated areas, e.g. *Juniperus communis* and *Vaccinium myrtillus*. The swamp has expanded slightly into the lagoon and the willow zone into the swamp zone.

Area D: In this area the formation of the northeastern lagoon border started.

Area D1 and D2. In 1904 the extreme end of this levee constituted an uncolonized bar, *area D1. Area D2,* the central part, was covered by willows and the rest with pioneer vegetation. In 1922 the willow vegetation at D2 was more marked. D1 was still poorly covered by vegetation. In 1974 the area D2 is still dominated by willow vegetation but a few birches have developed. In the part of area D1 that was highest in 1904 there are now young willow stands and swamp vegetation has developed on the part bordering the lagoon.

Area D3. Constitutes the cleavage bar which caused the formation of the channel that still connects the lagoon-water area with the delta distributary. The bar was built up between 1899 and 1922. In 1922 this area was a sparsely vegetation-covered bar. In 1974 the western and northern parts are covered by 0.5–1 m high willow shrubs passing into a pioneer swamp vegetation bordering the lagoon.

Area D4. Consists of the miniature delta formed by the channel in the lagoon. In 1954 the channel passing into the lagoon was rather short. In 1974 the miniature delta extends to about half the length of the lagoon and is growing rapidly, forming the eastern border of the lagoon.

Area G: Constitutes the connection to Lake Laitaure (see Figs. 40 and 16). In 1954 this passage was very shallow and dried out at low water. In 1974 the central part of the area has been deepened and works as a channel to lagoon 69. Land is continuously being built up along the channel.

Area F: This area constitutes the swamp and willow shrub zones along the southern and northern lagoon border formed by the two distributaries Kuoutätno and Nuourtätno, both here chiefly running in the general stream direction. The differences in the vegetation in these areas between 1904 and 1974 are very small as regards the extension of the different zones. Almost all irregularities in the willow zone found in 1904 are still detectable but the swamp zone seems to have expanded. In a few places small willow shrubs have invaded the swamp zone.

5.2.2. Lagoon 71

This lagoon is formed in connection with till island No. 4 (see Fig. 4) situated east of the lagoon. The interlevee basin lies between the Kuoutätno and the Årjeliätno. The western border has been formed by a delta distributary crossing the interlevee basin. The southern and northern levees are well-developed but only the southern one is covered by birches. The depth of the lagoon is around 1 m.

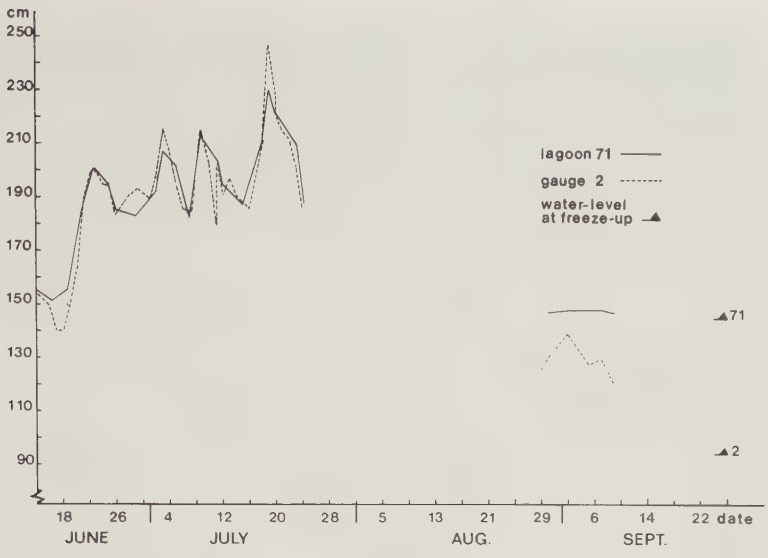


Fig. 44. Daily water-level variation in 1973 in lagoon 71 compared with that of Kuoutätno 2 and the water-levels at freeze-up in the lagoons. 150 cm is equivalent to 494.8 m above M.S.L.

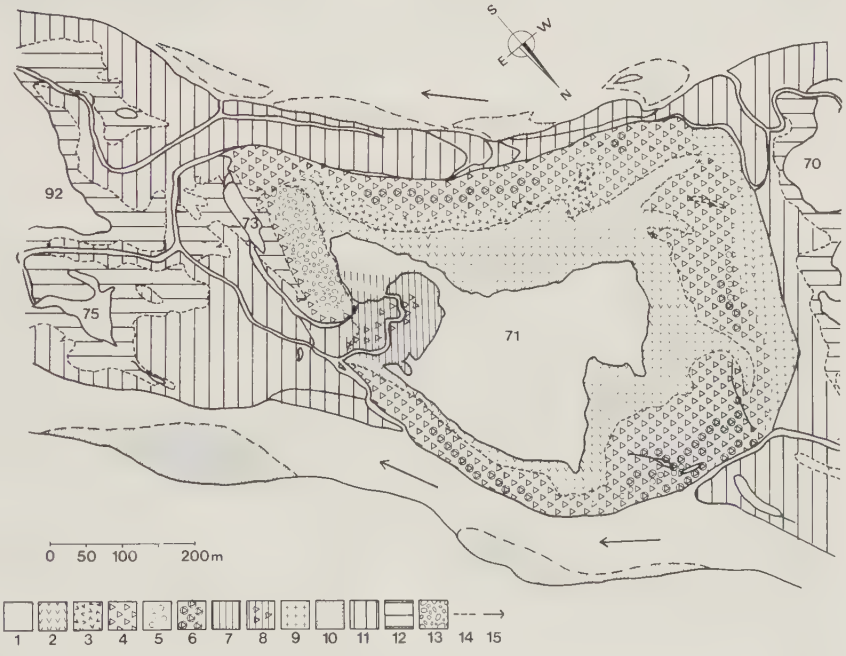


Fig. 45. Development of vegetation around lagoon 71 between 1904 and 1974. For the development of the miniature delta see Fig. 46. 1. Open water during the whole period; 2. Swamp vegetation, unchanged; 3. Swamp vegetation in 1904, invaded by willow shrubs; 4. Willow shrub vegetation in 1904, with unchanged good vitality; 5. Unchanged occurrence of birches; 6. Birch establishment in willow vegetation during the period; 7. Pioneer vegetation, developed to swamp vegetation; 8. Pioneer vegetation, developed into willow vegetation, covering the levee ridge; 9. Levee-closed distributary-landscape with birch, willow and swamp vegetation; 10. Sand bar with scattered pioneer vegetation in 1974; 11. Willow or birch vegetation in 1974; 12. Swamp vegetation in 1974; 13. Till; 14. Border between swamp vegetation and willow or birch vegetation in 1954; 15. Direction of current. Solid lines represent water-courses with or without open water, long hatched lines; see Fig. 3.

In 1904 the lagoon probably had the same water-level variation as the active delta distributary, since the outflow was short and no miniature delta was developed. Except for the miniature delta, the lagoon has the same form today as in 1904.

5.2.2.1. Hydrology

The channel which is building up the miniature delta splits in two close to its outflow into the Kuoutätno. One short channel from the Kuoutätno acts as an inflow to the lagoon channel and the other, a long, narrow distributary which passes all the way to Laitaure through lagoons 75 and 92, works as main outflow (see Fig. 4). The water-level variation in the lagoon (see Fig. 44) follows water-level gauge No. 2 almost perfectly at high and mean water-level but at low-water table the water-level in the lagoon does not fluctuate as much as in the distributary and is around 20 cm above distributary level. The lowering of the water-level is often delayed. At freeze-up the water-level in the lagoon lies about 50 cm above the water-level at water-level gauge No. 2. The water-level amplitude amounts to about 70 cm, extreme high waters excluded.

5.2.2.2. Description of the vegetation in and around the lagoon in 1974

Open water vegetation: In sheltered areas in the eastern part *Eleocharis acicularis – Subularia aquatica* vegetation covers the bottom. In the deeper western part, to which the turbid distributary water does not often reach, the lagoon bottom is covered by *Potamogeton alpinus – Sparganium* sp. vegetation. *Ranunculus confervoides* also occurs frequently.

Swamp vegetation: The reedswamp around the lagoon is dominated by *Carex aquatilis* without a sod. *Equisetum fluviatile* can also be found. Depending on the slope and age of the interjacent swamp there is either a mixed graminid swamp or a moss-covered one.

5.2.2.3. The delimitation of lagoon 71 and the development of vegetation from 1904 to 1974

New land has only been built up (see Figs. 46 and 47) in connection with the miniature delta formation which has now almost divided the lagoon into two. Fig. 45 shows the vegetation development from 1904 to 1974 and Fig. 49 the lagoon in 1974. For location of the different areas described see Figs. 48 and 49.

Area A: Consists of the distributary passing between the Kuoutätno and the Årjeliätno. In 1904 this distributary was open at both ends and comparatively broad. Upstream of distributary A the vegetation was poorly developed and lower than downstream in area C3. A large part of the distributary was filled with longitudinal bars with depressions in between. In 1922 the distributary was water-filled but it is not possible to see whether there was an active contact with any other distributary. The bar crests were covered by willow shrubs. In 1974 this distributary is closed at both ends and the water depth in the deepest parts is around 50 cm. The bar crests are covered by birches in rows and in the depressions in between there is a mixed sedge swamp, here and there replaced by open water, or a tussocky swamp, forming the vegetation cover. The willows closest to the swamp are dying. The upstream levee of distributary A is covered by willows but scattered birches are also found.

Area B: At this point the Kuoutätno once split, forming the channel to the lagoon and the distributary which partly works as an outflow. In 1904 there were no sandbars in the inflow (see Fig. 38 bottom), although bars could probably have been formed as early as this time. In 1922 the formation of a miniature delta inside the lagoon had started by accumulation of sediments forming a bar east of the channel, in connection with

Fig. 46. Vegetation and land at the channel-distributary junction of lagoon 71 and the delta front in 1904. 1. Open water; 2. Swamp vegetation; 3. Pioneer vegetation in places with low willows; 4. Willow vegetation; 5. Till; 6. Direction of current.

Fig. 47. Development of the miniature delta in lagoon 71 from 1904 to 1974. 1. Open water; 2 and 3. Permanent land in 1904; 2. Delta sediment; 3. Till; 4. Land formed in 1904–1922; 5. Land formed in 1922–1954; 6. Land formed in 1954–1965; 7. Land formed in 1965–1974; 8. Direction of current. Hatched line=border between till and delta sediments.

Fig. 48. Lagoon 71 from the north (Skerfe) in 1922. Comparatively low water-level. For explanation of the markings see section 5.2.2.3.

Fig. 49. Lagoon 71 from the north (Skerfe) in 18 July, 1970. Water-level in Lake Laitaure=116 cm. The position of the water-level gauge (Ø) is shown, as is the position of belt-transect 22 (tr 22) in lagoon 92. For explanation of the markings see section 5.2.2.3.

the till island (see Fig. 47). In 1954 this delta had almost divided the lagoon into two parts, the very shallow connection probably working as a low-water threshold. In 1974 the channel ends in a sand bar with pioneer vegetation. There is connection between the main lagoon and the channel only at relatively high water-levels. The levees of the channel are covered by young willow shrubs.

Area C: All the areas C1–C5 constitute the willow zone around the lagoon and in all these areas the willow vegetation was already developed in 1904.

Area C1. Situated along the Årjeliätno. In 1904 the levee was narrow and probably covered by willow shrubs. In 1922 a sand bar had been formed and cut off the area from immediate contact with the Årjeliätno. The willow vegetation was vital and high. In 1974 the part of the former willow zone close to the Årjeliätno is covered by fairly old birches standing at a comparatively low elevation. In the lagoon-ward part of the willow zone the lowest situated shrubs were dying. The willow zone may have expanded a little since 1904.

Area C2. Situated in the southwestern corner of the interlevee basin. In 1922 the willow vegetation was high and vital, which it probably was also in 1904. In 1974 the willow is high and vital and the swamp-covered area, clearly visible on the photo from 1922, was invaded by willow shrubs.

Area C3. Constitutes the broad willow zone downstream from distributary A. In 1904 the area was covered by willow shrubs. In 1922 the willow shrubs were vital and there was a very distinct border between the swamp vegetation and the willow-covered areas. A few birches had developed in the eastern part. In 1974 the willow zone has expanded out into the swamp. The area is very rich in boulders and the shrubs often grow close to them with a mixed sedge swamp in between.

Area C4. Constitutes the area formed along the Kuoutätno and along the southern distributary rejoining with the Kuoutätno west of the lagoon basin. In 1904 the area was covered by willows. In 1922 one and sometimes two rows of birches had developed, probably along a small distributary that was closed at the time. The willow zone was expanding into the swamp. In 1974 the willow shrubs have spread almost to the open water area, although growing on clumps formed by their own roots and stems and on stones. The vitality of the shrubs is usually between 3 and 2.

Area C5. Constitutes the narrow levee along the Kuoutätno. In 1904 there was probably a comparable young levee ridge covered by young, low willows. In 1922 the willow zone was distinct and well-developed. In 1974 the willow zone has the same extension as in 1922. The slope of the levee is comparably steep and the larger part of the willow zone is dry and has no field or bottom layers. A few birches have developed along the levee since 1922. The bar at the mouth of the inflow is covered by low willow vegetation.

Area D. The parts D1–D3 constitute the swamp vegetation around the lagoon. Nowhere has any floating swamp been found. The swamp zone succession is progressive.

Area D1. Situated along the Årjeliätno. In 1904–1922 the swamp vegetation seems to have expanded into the lagoon. In 1974 the swamp vegetation has expanded further and together with the miniature delta it has closed the western part of the lagoon. *Carex aquatilis* and *Equisetum fluviatile,* without a sod, dominate the reedswamp.

Area D2. Comprises the swamp vegetation in the western part of the basin. In 1904–1922, the swamp zone here again seems to have had a small extension. In 1974 the swamp zone is very broad and scattered shrubs are found everywhere. The reedswamp is dominated by *C. aquatilis* and tussocky from moss growth. There is open water among the willows in the swamp. A mixed sedge swamp dominates the interjacent and shoreward swamp.

Area D3. The narrow swamp zone along the Kuoutätno. In 1904 this area might have been covered by pioneer vegetation. In 1922 there was a narrow swamp zone which does not seems to have expanded since 1904. In 1974 the reedswamp is dominated by *C. aquatilis* growing on a 10 cm thick sod. The central and shoreward swamps are also dominated by *C. aquatilis* due to the narrow and steeply sloping shore.

5.2.3. Lagoon 51 and its interlevee basin, including lagoons 52, 53, 56, 89, 90, 91

Lagoon 51 occupies the first depression in a large interlevee basin formed after a bifurcation of the Kuoutätno (see Fig. 4). Lagoon 51 is the only lagoon intensively studied but hydrologically the basin works as a unit. Therefore, the other six lagoons in the basin are also dealt with, e.g. lagoons 52, 53, 56, 89, 90 and 91.

The levees surrounding the interlevee basin are high and well defined along the Kuoutätno, although mostly not covered by birches, while along the southern shallow and narrow distributary, which is quite often dry, the levees are comparably low.

Lagoon 51 was formed in connection with a till island and lagoon 89 was enclosed between the till island and the Kuoutätno's southern levee. Lagoons 90 and 91 are probably former distributaries or meander scroll depressions. No. 56 is probably a remnant of a former

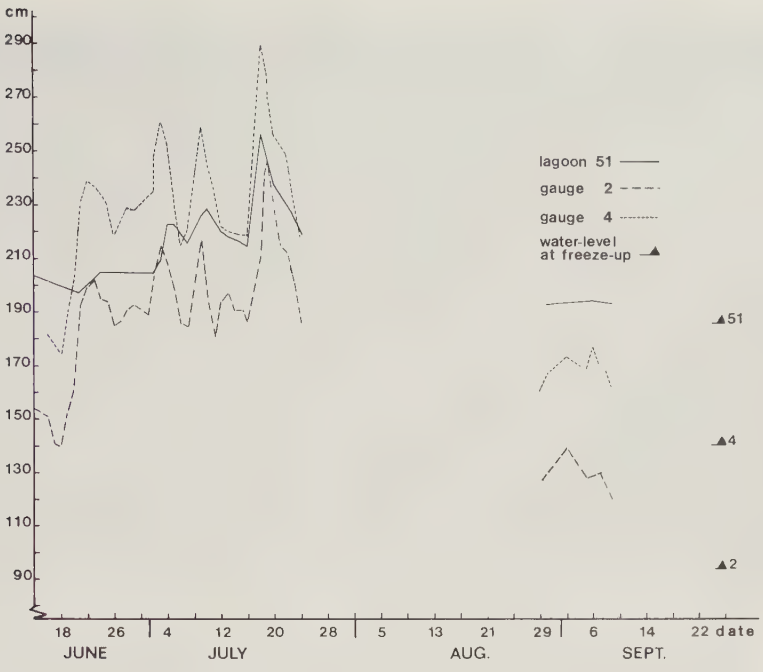


Fig. 50. Daily water-level variation in 1973 in lagoon 51 compared with that of Kuoutätno 2 and 4 and the water-levels at freeze-up in the lagoons. 150 cm is equivalent to 494.8 m above M.S.L.

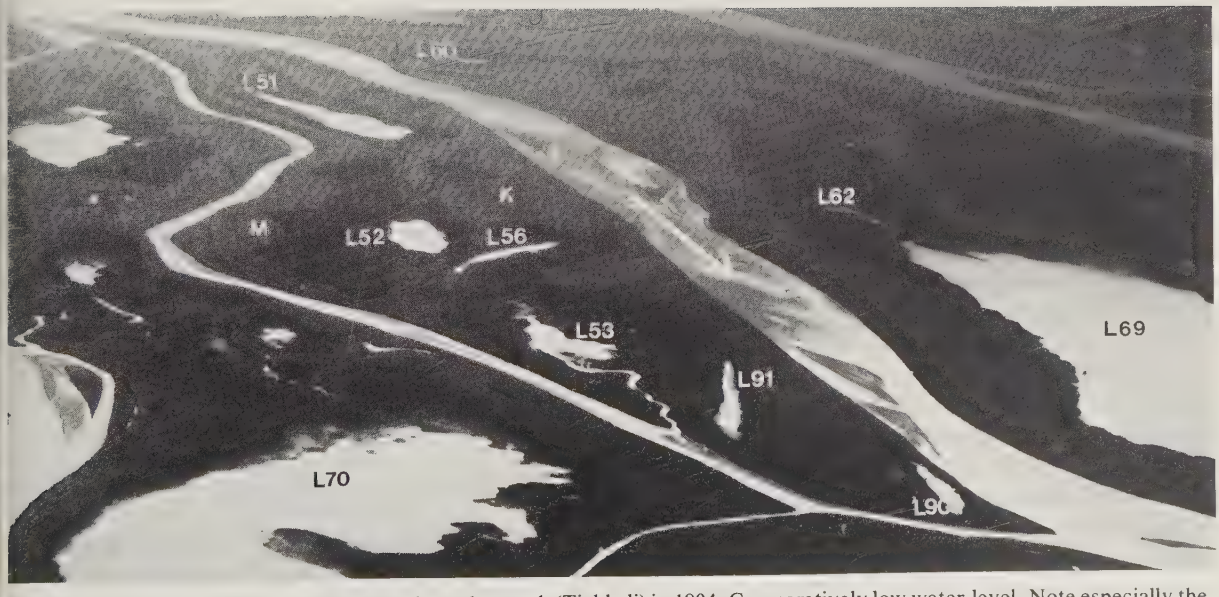


Fig. 51. Lagoon 51 and its interlevee basin from the south (Tjakkeli) in 1904. Comparatively low water-level. Note especially the open connection to lagoon 53. For explanation of the markings see section 5.2.3.3.

Fig. 52. Lagoon 51 and its interlevee basin from the north (Skerfe) in 1922. Comparatively low water-level. Compare especially the appearance of areas C1, C2 and C3 in 1922 and in 1972 (Fig. 53). For explanation of the markings see section 5.2.3.3.

distributary crossing the basin. The origin of lagoons 52 and 53 is not clear. They are probably former depressions sheltered from loading by different geomorphological or vegetational structures. Lagoon 52 lies behind areas K and M (see Figs. 51 and 52) and lagoon 53 behind the levee leading to lagoon 52. The areas between the lagoons are covered by swamp vegetation.

5.2.3.1. Hydrology

During the time period documented by photos the interlevee basin has had only two outflows, the channels leading from lagoons 52 and 53 to the southern delta distributary. The channel from lagoon 52 has been closed since 1922 by a threshold at the connection between the lagoon and the channel. The channel from lagoon 53 has a low-water threshold but is still open.

The water-level variation shown in Fig. 50 follows to a certain extent the variation in the Kuoutätno. The rising of the water-level is faster than the lowering, presumably due to the low areas along the levees. The levees are locally very narrow and water may seep into the basin through them. The water-level in the lagoon follows water-level gauge No. 2, close to the outflow, better than gauge No. 4 which is situated close to the lagoon (51). The water-level amplitude amounts to 40 cm, extreme high water excluded. During the extreme high water in 1973 the levees were drowned and, lagoon 90 for example, emptied directly into the Kuoutätno. At freeze-up the water-level in the lagoon was about 120 cm above gauge No. 2 and 20 cm above gauge No. 4. There is usually 20 to 30 cm deep water in the interjacent willow subzone at freeze-up.

5.2.3.2. Description of the vegetation in and around the lagoons in 1974

Willow shrubs are dying all around the shores of this basin, as also are the birches in a few areas.

Open water vegetation: Only *Potamogeton alpinus – Sparganium* sp. vegetation and *Drepanocladus trichophyllus – Calliergon cordifolium* vegetation are found in the lagoons. In all the lagoons vegetation covers the whole bottom.

Swamp vegetation: Almost the whole area between the lagoons is covered by a mixed sedge swamp which floats here and there. Depending on age, the thickness of the sod varies. Mixed graminid swamp and moss-covered swamp occur very rarely.

Willow vegetation: Most willow shrubs are dead or dying but there are still remnants in almost all areas where willows have grown. The willow zone with vital willows is comparatively narrow.

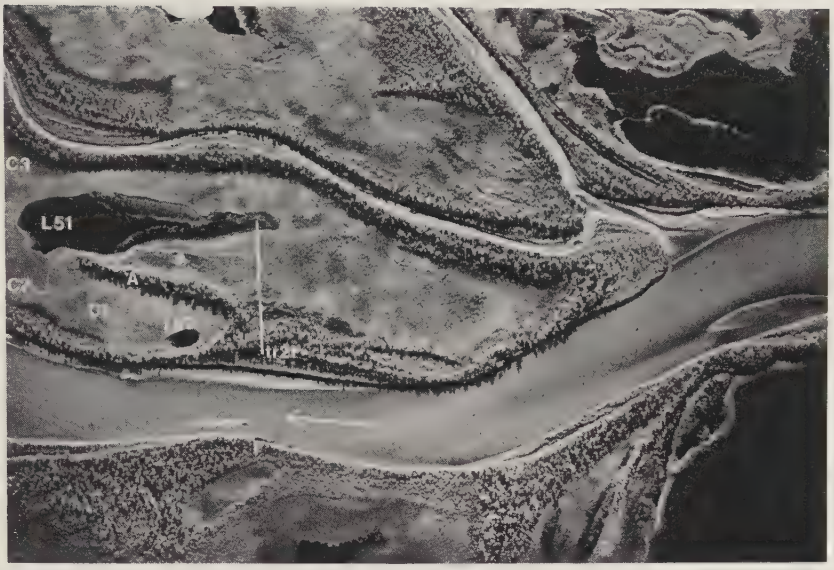


Fig. 53. Lagoon 51 from the north (Skerfe) in 1972. Water-level in Lake Laitaure=145 cm. The water-level gauge in the lagoon (Ø) and belt-transect 21 (tr 21) is also shown. Note the tussocky reedswamp and the disappeared willow vegetation in areas C1, C2 and C3. For explanation of the markings see section 5.2.3.3.

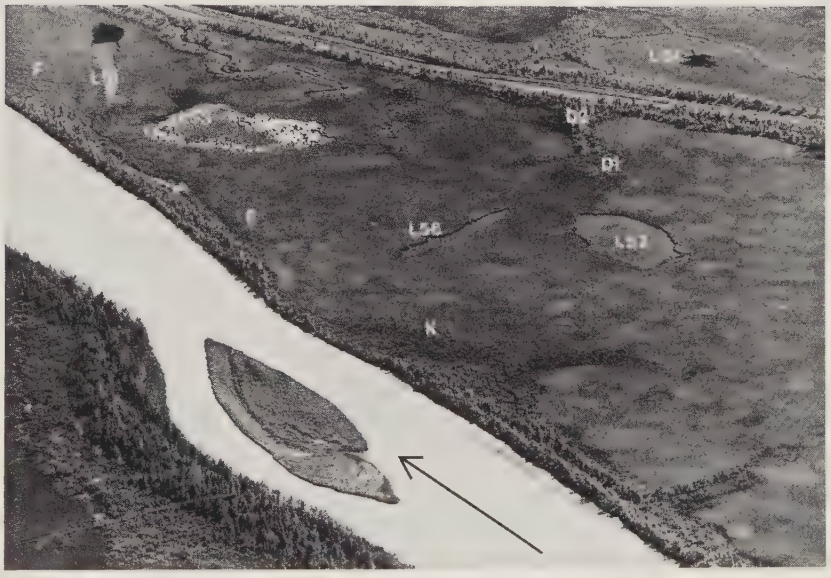


Fig. 54. Lagoons 52, 53, 56 and 91 from the north (Skerfe) in 25 July 1974. Water-level in Lake Laitaure=152 cm. Note the closed channel to lagoon 53 and the deteriorated willow vegetation in area K. The reedswamp in lagoons 52, 56 and 91 is somewhat tussocky. For explanation of the markings see section 5.2.3.3.

5.2.3.3. Development of vegetation and land in the interlevee basin from 1904 to 1974

For location of the lagoons and the different areas described see Figs. 51, 52, 53 and 54. The vegetational development is shown in Fig. 55.

Lagoon 51

Potamogeton alpinus – Sparganium sp. vegetation is the only water vegetation in the lagoon.

Between 1922 and 1954 (see Fig. 55) the western part of the lagoon became invaded by swamp vegetation. Judging from the existing vegetation and its structure, the reedswamp in 1922 was probably dominated by *Carex aquatilis* on a rhizome blanket. *Carex rostrata* then developed in the lagoon and the reedswamp with *C. aquatilis* extended further out into the lagoon. In 1965 the newly developed swamp area was very distinct on the air-photo (see Fig. 17 and 52; cf. also lagoon 50). In 1971 the swamp in this area was disintegrating. There were large solitary standing clumps of *C. aquatilis* in the formerly continuous swamp and the *C. rostrata* specimens were growing apart. In 1974 disintegration continued (see Fig. 53).

The extension of the willow zone and the vitality of the shrubs in the western part of the basin cannot be interpreted on the photos from 1904 and 1922. In 1974 all shrubs in the swamp are dead or dying. The water

Fig. 55. Development of vegetation in the levee basin surrounding lagoons 51, 89, 52, 53, 56, 90 and 91, from 1904 to 1974. Full lines indicate abandoned water-courses, long hatched lines see Fig. 3. 1. Open water during the whole period; 2. Swamp vegetation, unchanged; 3. Swamp vegetation replaced by open water between 1904 and 1974; 4. Open water 1904 where swamp vegetation developed, disintegrating 1974; 5. Open water in 1904, some of it developed to a *Carex rostrata* reedswamp, disintegrating in 1974; 6. Willow shrub vegetation with unchanged good vitality; 7. Willow shrub vegetation which has died during the period or is dying and invaded by swamp vegetation; 8. Willow shrubs which have disappeared totally; 9. Pioneer vegetation which has developed into willow vegetation; 10. Unchanged occurrence of birches; 11. Birches which have died during the period or are dying; 12. Birch establishment in willow vegetation during the period; 13. Birch-covered areas influenced by wind-blown sediments; 14. Sand bar with scattered pioneer vegetation in 1974; 15. Till; 16. Border between swamp vegetation and willow or birch vegetation in 1954; 17. Direction of current.

depth in the interjacent part of the willow zone at mean water stage is around 30 cm, and the vitality of the shrubs between 0 and 2 (see section 4.1).

Area A. The former till island. In 1904 this island was covered by birchwood. In 1974 the willow zone bordering the birch-covered island is dead or dying. Only the willows close to the island are healthy.

Area B. Constitutes the mostly swamp-covered area enclosed behind the till island and a willow-covered levee area, C1. Lagoon 89 is situated in the western corner of the swamp.

In 1922 the swamp was interrupted by dark patches, probably consisting of open water areas or willow shrubs. In 1974 the swamp was comparatively homogeneous.

Lagoon 89

Potamogeton alpinus – Sparganium sp. vegetation is the only water vegetation. The reedswamp surrounding the open water area is a *Carex rostrata* reedswamp abutting shoreward to a *Carex aquatilis* floating swamp. There is a 0.6 m difference in level between the *C. rostrata* and the *C. aquatilis* swamp (see Fig. 29).

Area C: Willow vegetation situated to the east of lagoon 51.

Area C1. In 1904 and 1922 there was a well-defined levee ridge covered by willow shrubs in this area. In 1974 hardly anything is left of the willows in the now swamp-covered area.

Area C2. A triangular willow-covered area almost reaching the island. Between 1904 and 1922 the willow zone seems to have expanded. In 1974 the part of the willow zone close to the lagoon has disappeared totally and in the rest of the area, the levee crest excepted, the shrubs are dying. An *Eriophorum angustifolium* swamp has developed in the formerly willow-covered areas. On the levee crest along the Kuoutätno a few birches have grown up since 1922.

Area C3. In 1904 this area together with area K almost divided the interlevee basin. In 1904 there was a complicated pattern of willow-covered levee ridges in the area. In 1922 the willows situated at the extreme end of levees had died. In 1974 only the part of the levee close to the distributary is covered by living willows, although white sticks of *Salix* remain in the swamp that now covers the former willow zone.

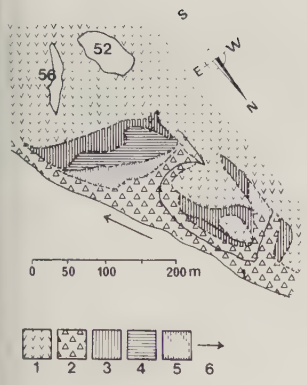


Fig. 56. The retrogression of the willow zone in area K, in the interlevee basin of lagoon 51. Full lines indicate abandoned water-courses, hatched lines=border between areas with different vegetation. 1. Swamp vegetation, unchanged; 2. Willow shrub vegetation with unchanged good vitality; 3. Willows that died between 1922 and 1954; 4. Willows that died between 1954 and 1965; 5. Willows that (became less vital) died between 1965 and 1974; 6. Direction of current.

Area K. This area shows a very complicated pattern of short, straight or bent former distributaries with their levees. The origin is probably two very unsuccessful bifurcations of the Kuoutätno. For the disappearance of the willows in the area, see Fig. 56.

In 1904 there were only willow shrubs in the area and the former distributaries are visible on the photo. In 1922 birches had developed along the larger levees. In 1974 only the part close to the Kuoutätno is covered by living willows. The birches are all dead or dying.

Lagoon 52

Drepanocladus trichophyllus – Calliergon giganteum vegetation covers the open water area of the lagoon. The mosses are between 0.7 and 0.9 m long and reach the surface of the water. The swamp around the lagoon is a *Carex aquatilis* swamp on a thick sod.

Between 1904 and 1922 the area of the lagoon does not seem to have changed. In 1974 the reedswamp has begun to disintegrate.

Lagoon 56

Drepanocladus trichophyllus and *Calliergon giganteum* fill the lagoon totally and a *Carex aquatilis* swamp on a sod surrounds the open water.

In 1904 there was a small water area south of the open water of today (1974). An open connection between today's lagoon and the former distributary may have existed, working as a channel passing to the southern distributary. In 1922 the lagoon had the same extension as in 1974. In 1974 there is no longer any connection between the lagoon and the southern distributary.

Area D. Constitutes the southern part of the former distributary crossing the interlevee basin and leaving lagoon 56 as a remnant. The area has also worked as a channel to lagoons 52 and 56, carrying water from the southern distributary.

In 1904 the levees were covered by willow shrubs and swamp vegetation had developed at the connection between lagoon 52 and the channel. In 1922 the willow zone had the same extension as in 1904. In 1974 the willows in area D1 are dead or dying. The swamp among the dying willows is dominated by *Eriophorum angustifolium*. In area D2 birches have developed and the willows are still healthy.

Lagoon 53

The bottom of the lagoon is covered by a mixture of *Drepanocladus trichophyllus* and *Calliergon giganteum* but *Potamogeton alpinus – Sparganium* sp. vegetation is also found. For the development of lagoon 53, see Fig. 57.

In 1904 the channel leading to the lagoon was wide open and was building a miniature delta in the lagoon. The open water area at low water was restricted to the southern part. At high water a photo from Mt. Nammatj shows numerous open water patches in the swamp along the northern levee. In 1922 the open water area was small compared with that of 1904 but situated in the same area. It is not possible to detect whether there was any low-water threshold in the channel but the former sandbars at the connection between the channel and the lagoon were covered by swamp vegetation. In 1954 the channel was open and water-filled except for the connection where swamp vegetation formed a low-water threshold. The open water area was small and situated in the northern part of the lagoon area. The areas formerly covered by water had developed into a swamp or a tussocky swamp. The reedswamp seems to be a tussocky swamp. In 1971 the open water area had enlarged compared with 1954, mainly towards the south. A large part of the lagoon could be classified as a tussocky lagoon. In 1974, after a high-water period, the open water area is still larger than in 1971 and the part which constituted the lagoon in 1922 was again turning into open water. The threshold had been built up of swamp vegetation at the connection between the channel and the lagoon.

This development of lagoon 53 can be explained in the following way. In 1904 the sedimentation was concentrated at the channel mouth thus sheltering from loading that part of the lagoon area which remained in 1971. After 1904 the channel altered direction from westerly to northeasterly, then sheltering all the lagoon area of 1904 from loading. Eventually the lagoon area

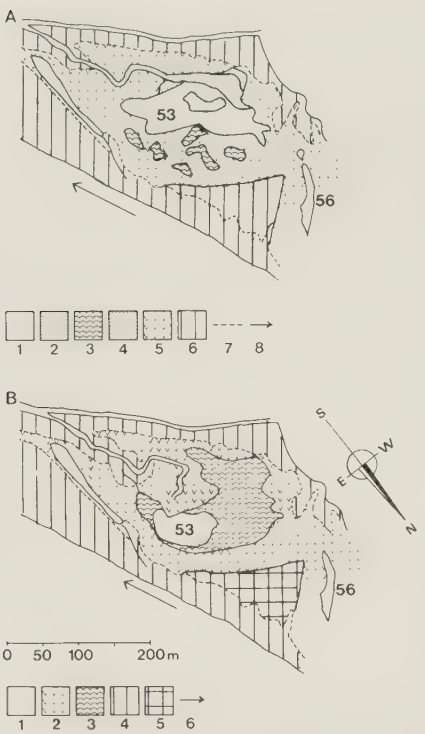


Fig. 57. A. Development of lagoon 53 between 1899 and 1922. 1. Open water at low water-level in 1904, covered by swamp vegetation in 1922; 2. Open water in 1904, the only area with open water in 1922; 3. Patches of open water at high water-level in 1904, swamp vegetation in 1922; 4. Sand bar in 1904, swamp vegetation in 1922; 5. Continuous swamp vegetation in 1904 and in 1922; 6. Willows or birch vegetation in 1904; 7. Border of willow vegetation in 1904; 8. Direction of current. Hatched line=border between swamp and willow or birch-covered land in 1954.

B. The distribution of open water and swamp vegetation in 1954. 1. Open water; 2. Continuous swamp vegetation; 3. Tussocky swamp vegetation; 4. Willow or birch vegetation in 1954; 5. Willow vegetation dead or dying; 6. Direction of current. Hatched line see Fig. 57 A.

of 1904 became covered by swamp vegetation, but as the low-water threshold later became higher, the formerly sheltered areas where the lagoon was situated in 1971 were first filled with water, and as the threshold grew the water area of 1904 opened up again.

Compaction of the silty sediments in the sheltered area of the lagoon might have added to the retrogressive development.

Lagoon 91

Small and elongated lagoon. The origin of the lagoon is not evident but it is probably a small former distributary which has been cut off at an early stage (see also lagoon 90).

Potamogeton alpinus – Sparganium sp. vegetation covers the bottom, together with *Drepanocladus trichophyllus – Calliergon giganteum* vegetation which, however, does not dominate. The depth is around 60 cm. The only species appearing in the swamp is *Carex aquatilis*.

In 1904 the lagoon was closed at both ends. Almost two-thirds of the south-western levee was covered by willow shrubs. In 1922 the willow shrubs were located as in 1904. Along the northeastern shore swamp vegetation formed the lagoon border. The route of the former distributary is clearly shown by the levee ridge which follows the lagoon and then curves downstream. In 1974 nothing can be seen of the former willow shrubs southwest of the lagoon, and on the northeastern side almost all remaining shrubs are dead. The area of open water does not seem to have changed much.

Area E: The willow-covered triangular area south of the beginning of the supposed former distributary, lagoon 91. The origin of the area is difficult to disclose probably because the erosion along the Kuoutätno has been very large and has destroyed the levee.

In 1904 the area had the same shape as in 1922 and from the photos the shrubs look healthy, although they are lower and more scattered, the further away from the Kuoutätno they get. In 1954 there were no signs of any living shrubs in this area except along the Kuoutätno's levee. In 1974 the area is covered by white sticks of willows overgrown by swamp vegetation.

Area F: Constitutes the area between lagoons 91 and 90 which probably was formed as a cleavage bar between the Kuoutätno and lagoon 91.

In 1904 and 1922 the area was covered by willow shrubs. In the latter year a few birches had developed. Two lighter-coloured spots *(areas G)* were probably covered by swamp vegetation. In 1954 the swamp vegetation covered a larger area than in 1922. In 1974 almost all willow shrubs are dead or dying, except along the levee ridges and along the Kuoutätno.

Lagoon 90

Small and elongated lagoon (see also 91). *Potamogeton alpinus – Sparganium* sp. vegetation appears in this lagoon but the lagoon bottom is covered by dead clumps of *Carex*. The shores of the lagoon are steep, the reedswamp is narrow and *Carex aquatilis* dominates.

In 1904 the lagoon was probably closed at both ends. The swamp vegetation seems to be expanding into the open water. In 1922 the lagoon had the same shape as in 1904. The southern levee was covered by willows and along the northern one a sandbar probably covered

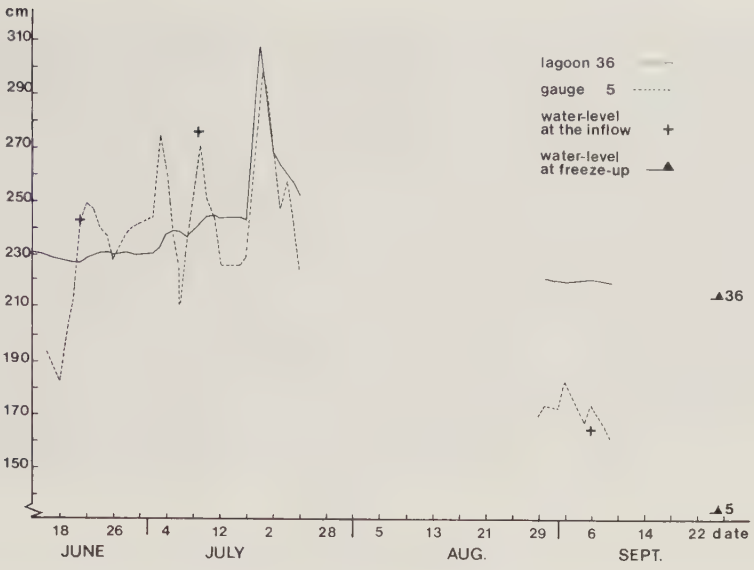


Fig. 58. The daily water-level variation in 1973 in lagoon 36 compared with that of Kuoutätno 5 and a few measurements at the channel-distributary junction. The water-levels at freeze-up in the lagoons are also shown. 150 cm is equivalent to 494.8 m above M. S. L.

by pioneer vegetation formed the lagoon border. In 1974 the willow shrubs along the southern levee are dying and the levee bordering the Kuoutätno is covered by young willows. At high water the lagoon empties directly into the distributary.

5.2.4. Lagoon 36

This lagoon is a part of a large interlevee basin formed at the first bifurcation of the Kuoutätno (see Fig. 4). The formation of the lagoon was probably influenced by the till island which also forms the eastern border. The western border was formed by a distributary crossing the interlevee basin and is now covered by dying willow vegetation. The tussock swamp between lagoons 36 and 13 is considered as the border to the west. The borders along the southern and northern shores are formed by the levees of active distributaries and the eastern border by a now disintegrating birch-covered levee. The lagoon is around 1.2 m deep in its deepest parts.

5.2.4.1. Hydrology

Today the interlevee basin has only one outflow, the one from lagoon 36 which has a very high low-water threshold. The threshold at the connection between the channel and the lagoon built up by swamp vegetation and deposited sediments is permanent, while at the connection between channel and distributary there is a non-permanent bar.

The water-level variation (see Fig. 58) is rather small but the rising and falling of the water-level at water-level gauge No. 5 can be noticed in the lagoon. At extreme high water all levee ridges were drowned, but normal water-level amplitude only amounts to 25–30 cm. A few measurements of the water-level were made in the distributary at the outflow of the channel (see Fig. 58). At low-water in the distributary the water-level in the lagoon was 55 cm above distributary level. At freeze-up the water-level in the lagoon was 70 cm above distributary level at gauge No. 5. The water was still 30–40 cm deep in the most shoreward swamp and in the willow zone.

5.2.4.2. Description of the vegetation in and around the lagoon in 1974

The bottom of large parts of the lagoon is covered by dead clumps of *Carex aquatilis* and by *Potamogeton alpinus – Sparganium* sp. vegetation in between. The swamp and willow vegetation will be dealt with below in the description of the development of the lagoon.

5.2.4.3. Development of vegetation and land around the lagoon from 1904 to 1974

The development of the vegetation is shown in Fig. 59. For location of the different areas described, see Figs. 60, 61 and 62.

Area A: The levees of the former distributary which crossed the inter-levee basin east of the lagoon, and of which lagoon 88 (see Fig. 4) is a remnant.

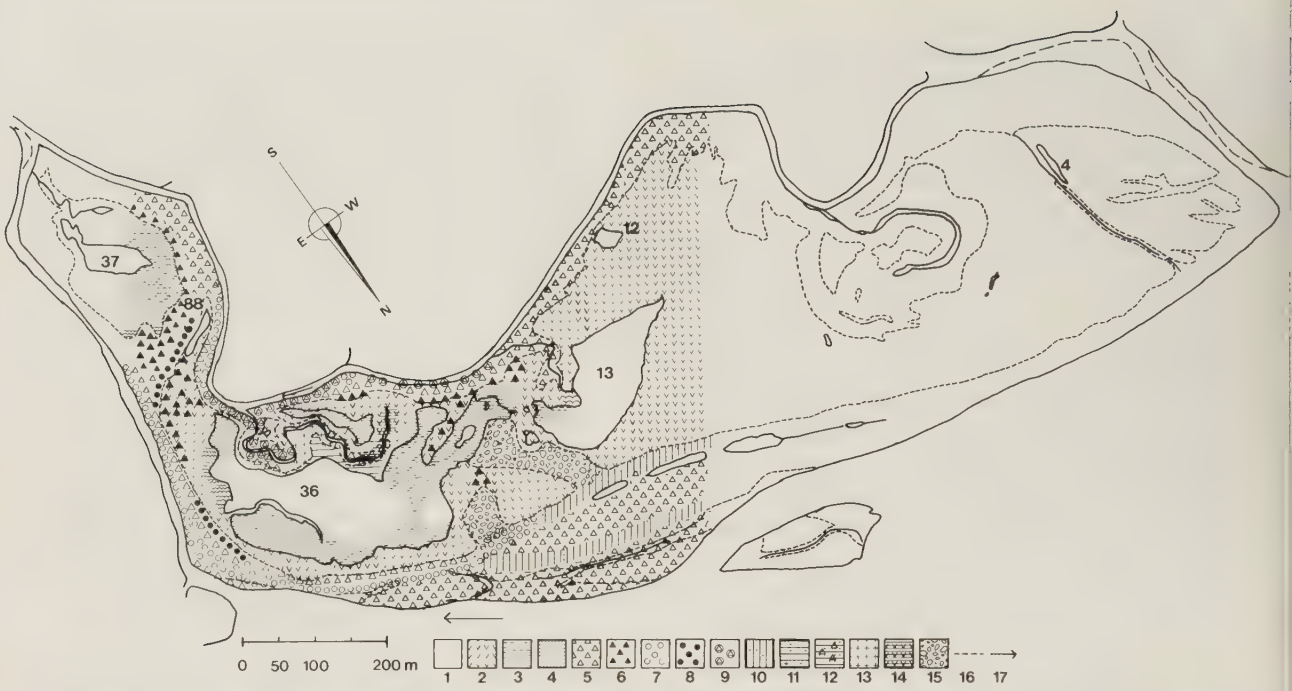


Fig. 59. Development of vegetation in and around lagoon 36 from 1904 to 1974. 1. Open water during the whole period; 2. Swamp vegetation unchanged; 3. Swamp vegetation replaced by open water; 4. Swamp vegetation disintegrated to tussocky swamp vegetation; 5. Willow shrub vegetation with unchanged good vitality; 6. Willow shrub vegetation which during the period has died or is dying, invaded by swamp vegetation; 7. Unchanged occurrence of birch; 8. Birches which during the period have died or are dying; 9. Birch establishment in willow vegetation during the period; 10. Birch covered areas influenced by wind-blown sediments; 11. Pioneer vegetation which during the period has developed into swamp vegetation with scattered willows; 12. Pioneer vegetation which during the period has developed into swamp vegetation, with scattered willows; 13. Pioneer vegetation which has developed into willow vegetation; 14. Open water which has developed into swamp vegetation; 15. Till; 16. Border between swamp vegetation (non-willow covered areas) and willow or birch vegetation in 1954; 17. Direction of current.

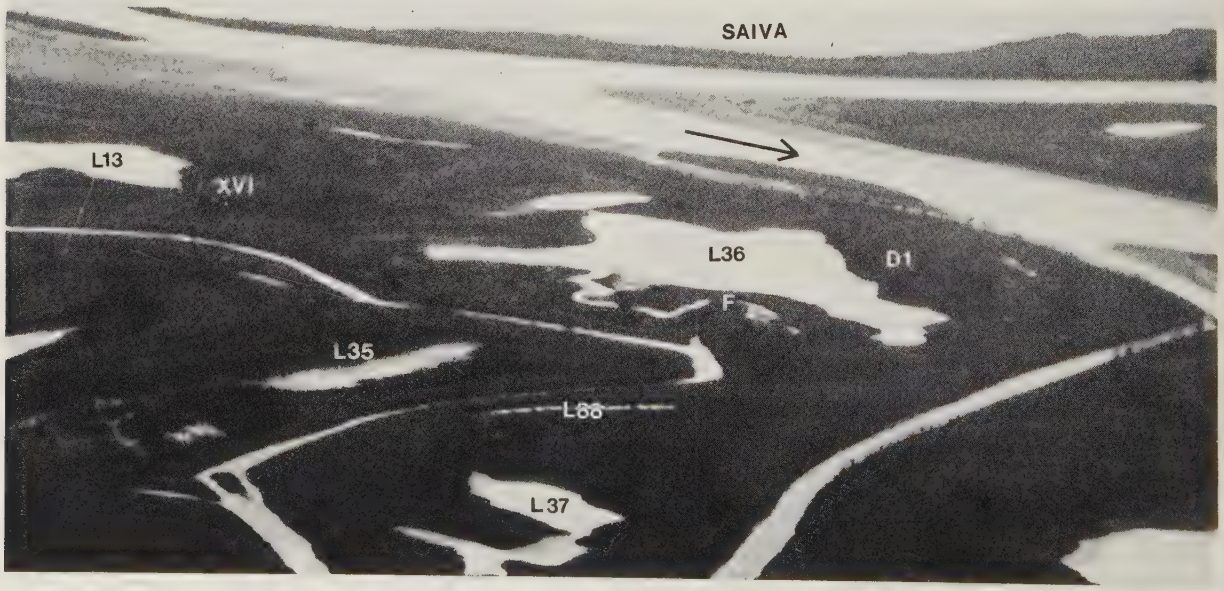


Fig. 60. Lagoon 36 from the south (Tjakkeli) in 1904. The channel was open and directed towards the north and there was a sand bar (area E) north of the channel. Relatively low water-level. For explanation of the markings see section 5.2.4.3.

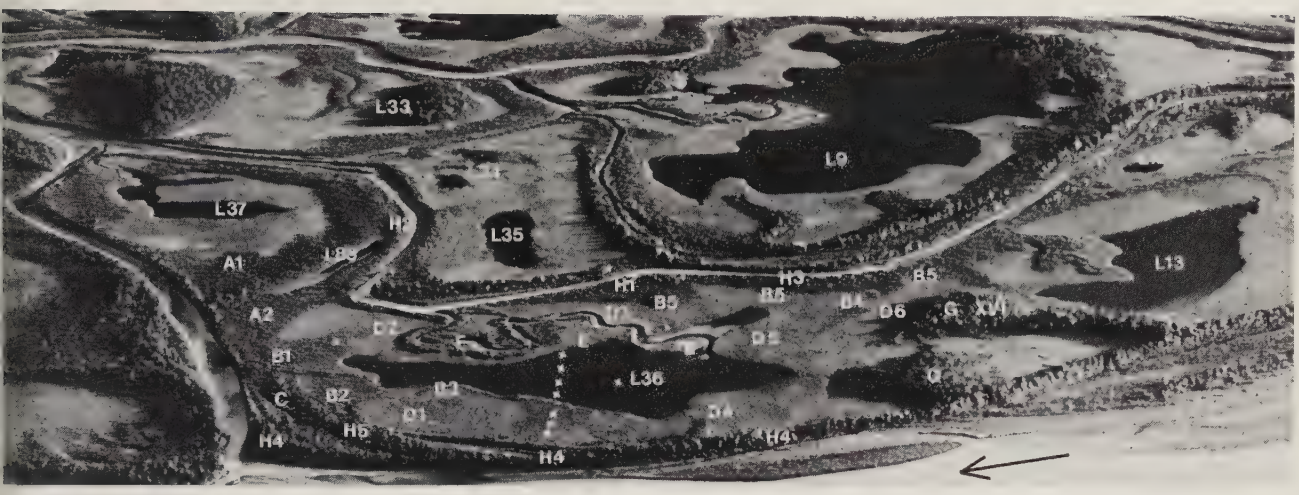


Fig. 61. Lagoon 36 from the north (Skerfe) in 1922. The channel was still directed towards north and open, although with a bar at the connection with the lagoon. The sampling points for the sediment cores presented in chapter 6 are indicated (crosses). For explanation of the markings see section 5.2.4.3.

Fig. 62. Lagoon 36 from the north (Skerfe) in 17 July, 1971. Water-level in Lake Laitaure=107 cm. The end of the channel in the lagoon points southward and swamp vegetation has disappeared over large areas. There is an open water connection to lagoon 13. The sediment core transect (see chapter 6) is indicated (full line) as also the position of the water-level gauge (Ø) in the lagoon. For explanation of the markings see section 5.2.4.3.

Area A1. The downstream levee. In 1904 there was a broad willow zone with one row of birches. In 1922 the birch-covered area was broader but the willow zone seems to have remained unchanged. In 1974 the willow zone is much narrower and most of it is dying. The birches are dead or half dead.

Area A2. The upstream willow-covered area. In 1904 there was a broad willow-covered area which extended across the interlevee basin. In 1922 the willow shrubs looked healthy. In 1974 nothing is left of the willows above swamp level but remnants of the shrubs can be found by walking through the swamp.

Area B: In 1922 all the areas B1–B5 were covered by willow shrubs, although they were formed at different times and as results of different processes.

Areas B1 and B2. Probably formed when the meander scroll C was developing, but they might also be remnants of an early channel to the lagoon. In 1922 the willows looked healthy and the zone might have been expanding out into the swamp. There were open areas, probably covered by swamp vegetation, between the shrubs. In 1974 hardly anything is left of the shrubs and the part of the areas close to the lagoon constituted a tussock swamp. There are, however, sticks of *Salix* still left in the swamp.

Area B3. Formed the northern border of the open water area in 1904 and in 1922. It might have been formed as a levee of a former distributary which was rapidly cut off. In 1922 there was at least one row of willow shrubs. In 1974 the western part is below water level, the willows are dead or dying and the vegetation is dominated by *Eriophorum angustifolium, Carex rostrata* and *C. aquatilis*. The eastern part is still above water-level but swamp vegetation prevails between the dying shrubs.

Area B4. A weakly developed levee which originated along a concave bend of the southern distributary. In 1922 there were low and scattered willow shrubs in this area, probably swamp-covered. In 1974 the formerly willow-covered part is covered by a homogeneous swamp while the rest of the area is tussock swamp or open water.

Area B5. The part of the willow zone close to the lagoon, along the southern distributary. In 1922 this area was covered by seemingly healthy willow shrubs. The breadth of the zone was variable, depending on the location behind bends of the distributary (see Fig. 4). In 1974, in the part of the zone closest to the lagoon, the willow shrubs are dead and the area is covered by swamp. Near the boundary towards the levee crest there is open water among the willows. Their vitality is between 1 and 2.

Area C: Constitutes the point bar landscape formed at the bifurcation of the Kuoutätno.

In 1922 the meander scroll depressions were visible but bordered by high willows and birches. No open water could be seen. In 1974 there is open water in the meander scroll depressions and the willows are dying.

Area D: In 1922 all the areas D1–D6 were covered by seemingly homogeneous swamp vegetation which in 1974 had become open water areas. They might have been in different stages of development in 1922 and have opened up at different times.

Area D1. In 1899 on a high-water photo there were patches of open water visible in the area. In 1922 there were a few depressions in the swamp vegetation. In 1974 the whole area is open water, although with tussocks along the shores. The bottom is covered by dead *Carex* clumps.

Area D2. Situated in a sheltered position behind the channel leading to the lagoon. In 1922 there was a continuous swamp. In 1974 there is open water in the whole area although the bottom is covered by dead clumps of *Carex*.

Area D3. In 1904 this area constituted the border of the open water but then became sheltered behind the channel as it grew into the lagoon. In 1904 this area was probably covered by pioneer vegetation, although it is now dominated by mixed sedge swamp. In 1922 the area was sheltered and a swamp had probably developed. In 1974 there is open water in this area, the bottom is covered by dead clumps of *Carex* but large clumps of living *C. aquatilis* still grow in the open water. This areas can be reached by sedimentation even at moderate high waters because the levee is low and situated downstream of the threshold.

Area D4. Probably developed as a result of the slight bend of the Kuoutätno which suggests a wider distribution of the sediments. In 1922 the area was covered by a homogeneous swamp vegetation. In 1974 the part of the area close to the lagoon is covered by open water and the rest by tussocky swamp.

Area D5. Probably developed in connection with the formation of area B4. In 1904 this area was the lagoon border and the miniature delta channel had not reached it. In 1922 the sand bars of the miniature delta had contact with this swamp-covered area. In 1974 the greater part of the area is covered by open water and the other part is a tussocky lagoon.

Area D6. In 1904 the area was covered by swamp vegetation. In 1922 the area was shaded by the birches of area G but there was probably a homogeneous swamp vegetation. In 1974 the till island borders on open water but there are still large clumps of *Carex aquatilis* present.

Area G: Consists of two former islands of till which probably always have been covered by birches. The shores border on the open water today but in 1922 they bordered on swamp vegetation or on a narrow willow zone.

Area E: Constitutes the area where the miniature delta has been built up since 1904.

In 1904 the area was covered by water but as the photo was taken at comparatively high water some bars might have been submerged. In 1922 the miniature delta had reached its final extension, although the channel which was open at this time has later changed its direction from north to south. The bars in the area might have been covered by pioneer vegetation. In 1974 the levees are covered by young willow vegetation, with field and bottom layers dominated by species tolerant to wetness. The swamp vegetation bordering the levee crests is a mixed sedge swamp in places with a sod. The channel ends in a mixed graminid swamp and is in places about 20 cm deep and 30 cm wide. The channel in this part is filled with vegetation; *Carex rostrata, C. aquatilis* and *Alopecurus aequalis* being the most frequent species.

Area F: The meandering lagoon channel, the levees of which were covered by vegetation in 1904.

In 1904 the channel was wide and filled with water, and the levees were probably covered by sparsely distributed willow shrubs. In 1922 the levee crests were covered by willow shrubs. There was probably a mixed graminid swamp bordering the willow vegetation which is shown in the sediment transect in Fig. 70. In 1974 birches have developed here and there along the levees, and the willow vegetation is dense and vital except on the border towards the swamp vegetation where the shrubs are dying.

Area H: Constitutes an area where birches grew in 1922.

Areas H1–H3. Situated along the southern levee. In 1922 there were only scattered birches, ten–twenty trees at the most, in these areas and the rest of the levee was covered by willow shrubs. In 1974 birches grow along the whole length of the levee, although in most parts only in one row.

Area H4. The levee along the Kuoutätno. In 1922 the whole levee was covered by birches mostly growing in one or two rows except at the point of bifurcation where a point bar landscape had developed. See also areas C and H5.

Area H5. Constitutes the innermost point bar formed at the bifurcation. In 1922 the birches in the area seemed vital but in 1974 they are dead or dying.

5.2.5. Lagoon 60

This lagoon is situated between the Kuoutätno and the Nuourtätno, inside the large interlevee basin formed at the bifurcation of these two distributaries. The lagoon area was embayed between the levees of two non-successful bifurcations of the Kuoutätno (see Fig. 4), one upstream, called A (Fig. 66) and one downstream, called area P. The northern boundary is formed by the levees of the Nuourtätno and the southern one by the levees of the Kuoutätno. The southern border is very narrow and low due to severe erosion. To the northeast there is a continuous swamp in contact with lagoon 62.

5.2.5.1. Hydrology

There is no evident channel connecting lagoon 60 with any distributary or other lagoon. The swamp-covered area must therefore work as a broad outflow from the lagoon. The inflow may take the same route but could also come either across or through the levees. The outflowing water has to pass through lagoon 62, across the swamp connection between lagoons 62 and 69, through lagoon 69 and all the way down to Lake Laitaure. The threshold which is thus probably situated somewhere in the swamp may be raised slowly, partly due to an increased thickness of the sod and partly due to fine-grained sediment being trapped in the swamp vegetation.

The water-level variation is shown in Fig. 63. The level of the water equals that at water-level gauge No. 1 at high water, but does not sink to such low levels at low water. The water-level at gauge No. 5 in the Kuoutätno outside the basin lies about 80 cm above the lagoon level at high water. This was, however, enough for the water to overflow the levee and fill the basin. After the overflow had ceased, the water-level in the lagoon returned to normal in a few days. During the extreme high water of 18 July 1973 the whole basin was filled and there was streaming water in area A. At freeze-up the water-level in the lagoon equals water-level gauge No. 5 while the water-level at gauge No. 1 is about 100 cm lower. The maximum water-level amplitude, extreme high water excluded, amounts to only 25–30 cm.

5.2.5.2. Description of the vegetation in and around the lagoon in 1974

Open water area vegetation: Consists of *Potamogeton alpinus – Sparganium sp.* vegetation.

Swamp vegetation: The reedswamp is dominated by *Carex aquatilis* on a sod. In the southwestern part the reedswamp is tussocky and dominated by *Eriophorum*

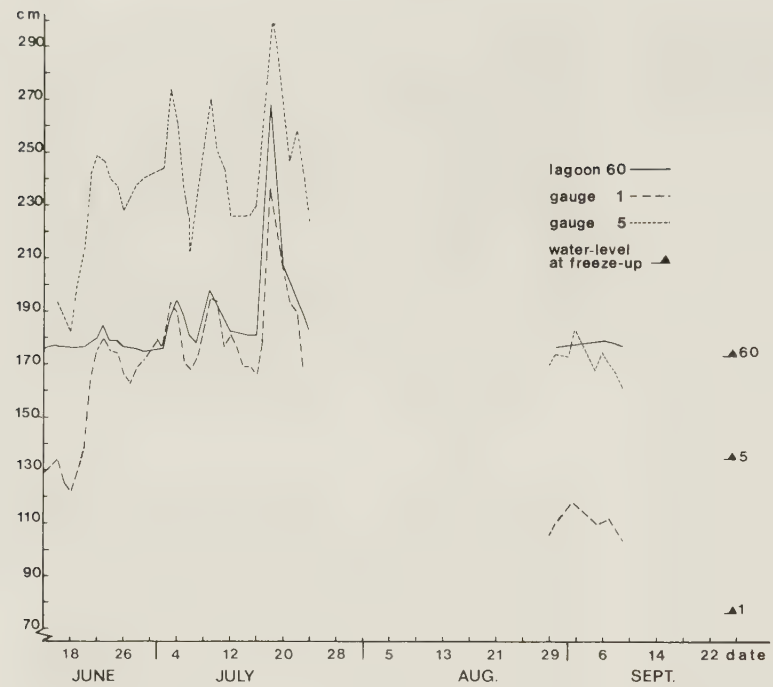


Fig. 63. Daily water-level variation in 1973 in lagoon 60 compared with that of Kuoutätno 1 and 5 and the water-levels at freeze-up in the lagoons. 150 cm is equivalent to 494.8 m above M.S.L.

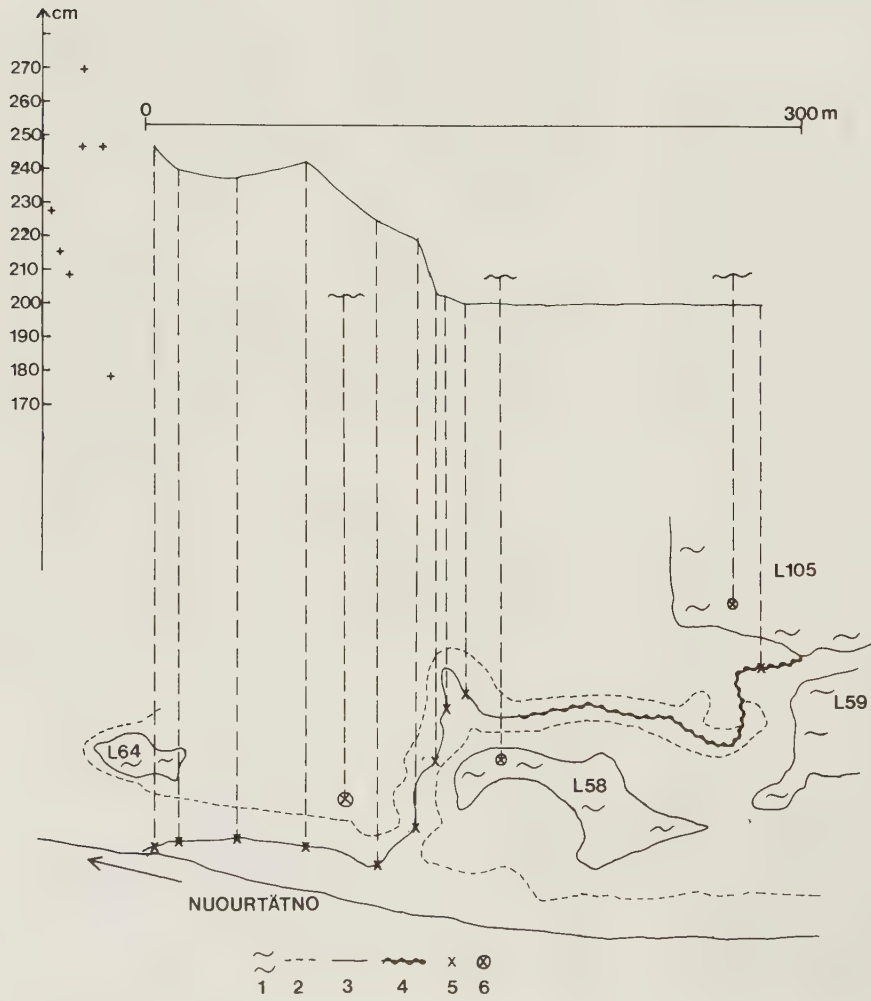


Fig. 64. The ground level and the water-level in and around the closed channel to lagoon 105. A few water-levels in the distributary Nuourtätno close to the channel-distributary junction are shown. 1. Open water; 2. Border between swamp vegetation and willow vegetation in 1954; 3. Channel; 4. Parts of the channel which are water-filled; 5. Measuring point for the ground surface in the channel bottom; 6. Measuring points for water-levels. Height of water-levels.

Fig. 65. Development from 1904 to 1974 of vegetation in the levee basins of lagoons 105 and 60. 1. Open water during the whole period; 2. Swamp vegetation unchanged; 3. Swamp vegetation replaced by open water; 4. Swamp vegetation disintegrated to tussocky swamp vegetation; 5. Open water colonized by swamp vegetation (lagoon 60); 6. Swamp-willow vegetation developed to swamp vegetation; 7. Willow shrub vegetation with unchanged good vitality; 8. Willow shrub vegetation which has died during the period or is dying and invaded by swamp vegetation; 9. Willow shrubs developed in swamp vegetation following heavy overbank deposits due to levee erosion (lagoon 60); 10. Unchanged occurrence of birches; 11. Birches which have died during the period or are dying; 12. Birch establishment in willow vegetation during the period; 13. Birch-covered areas influenced by wind-blown sediments; 14. Sand bar with scattered pioneer vegetation in 1974; 15. Border between swamp vegetation and willow-birch vegetation in 1954; 16. Direction of current. Long hatched lines see Fig. 3. Solid lines indicate abandoned water-courses.

angustifolium, *Carex rostrata* and *Equisetum fluviatile*. The interjacent and shoreward swamps have different vegetation depending on position and age.

Willow vegetation: The willows around the lagoon are healthy although the part of the zone close to the lagoon is covered by dying willow vegetation. The willow zone is comparatively broad.

5.2.5.3. Development of the lagoon and the vegetation from 1904 to 1974

The development of the vegetation around the lagoon is shown in Fig. 65. For location of the different areas described, see Figs. 66 and 67.

In 1904 the vegetation of the reedswamp of the lagoon looked rather even. In 1974 the lagoon is smaller than in 1904, especially at the western tip, and it has been invaded by swamp vegetation. The reedswamp is breaking up into clumps in 1974 and the vegetation at the western tip is dominated by *Eriophorum angustifolium* and *Equisetum fluviatile*.

Area P: Built up in connection with the bifurcation downstream of the lagoon. In 1904 the whole area was covered by willow shrubs except for a few small patches which probably were covered by swamp vegetation. In 1974 there is a single row of birches along the former levee ridge of the distributary. The open patches have enlarged, there is often water above the swamp level and some of the willows around are dying. In area P some of the willow shrubs have almost totally disappeared. The willow thicket close to the Kuoutätno is still healthy and almost impossible to penetrate.

Area M: Consists of the levee bordering the Kuoutätno. In 1904 the area was covered by willow vegetation, probably young. In 1974 a row of birches had developed along the levee crest while the willow vegetation present in 1904 was still healthy. The birches are young in 1974, but are gradually falling into the Kuoutätno as the levee become eroded. The willows are at the moment expanding out into the swamp. This expansion is promoted by the thick sedi-

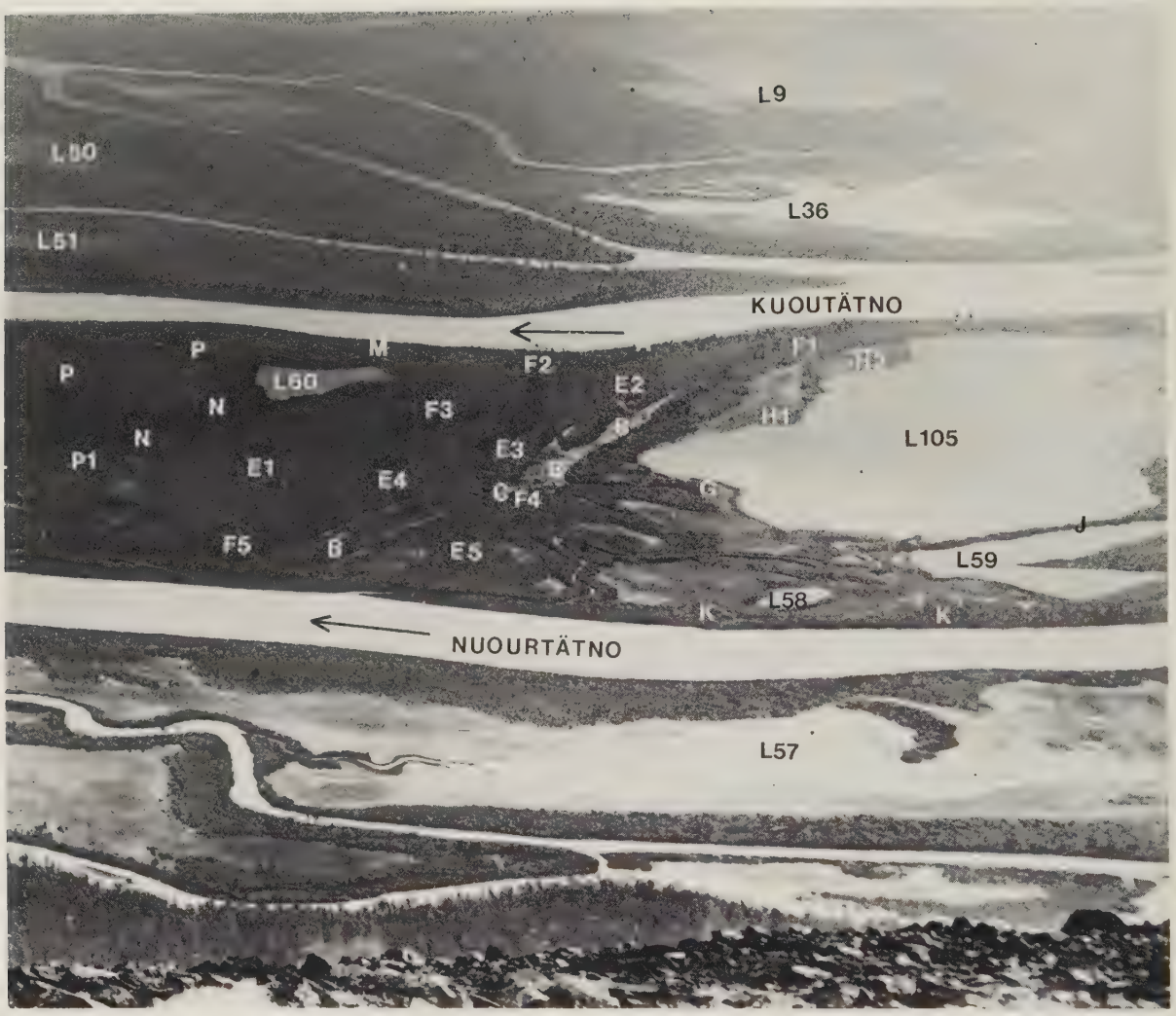


Fig. 66. Lagoons 60 and 105 from the north (Skerfe) in 1904. Relatively high water-level. No above-ground drainage from lagoon 60 can be detected but the open water area of lagoon 60 seems to have diminished in 1904–1974. An open channel connection to lagoon 105 can be presumed to have existed. It is not possible to decide whether the willow vegetation in area G and east of this area was flourishing. At the position of lagoons 64–67 there was swamp vegetation except in area C. For explanation of the markings see sections 5.2.5.3 and 5.2.6.3.

ment deposited in this area at every high water. In 1973 it was covered by 20–30 cm of sandy material (see Fig. 67). Similar deposition is also taking place in the western part of lagoon 4 (see Fig. 4).

Area N: Comprises the swamp vegetation around lagoon 60 and the area between lagoons 60 and 62.

In 1904 the swamp around the lagoon looked homogeneous. The area between the lagoons shows lighter-coloured spots and a pattern which resembles that of a meandering channel. These lighter areas could either be lower water-covered areas or areas with sparse vegetation where the light-coloured sediment shows up. In 1974 also the swamp between the lagoons seems to be homogeneous although some areas has a different appearance.

Area F2. The willow-covered area forming the upstream border of the lagoon. In 1904 the area was covered by apparently healthy willow shrubs. In 1974 the part of the willow zone close to the lagoon is dying, and there is 50 cm deep water, at mean water stage, in the part of the willow zone close to the levee. The field-layer vegetation is dominated by *Carex rostrata* and *C. juncella* together with *C. aquatilis*. For the development of areas E1 and F3 see section 5.6.

Fig. 67. Lagoons 60 and 105 from the north (Skerfe) in 25 July, 1974. Water-level in Lake Laitaure=152 cm. The water-level gauge in lagoon 60 (Ø) is marked. Belt-transect 33 is seen to the right. Note the *Carex aquatilis* clumps in the lagoons 64–67 which were covered by swamp vegetation in 1904. Note also the sandy overbank deposit along the River Kuoutätno south of lagoon 60 (area M).

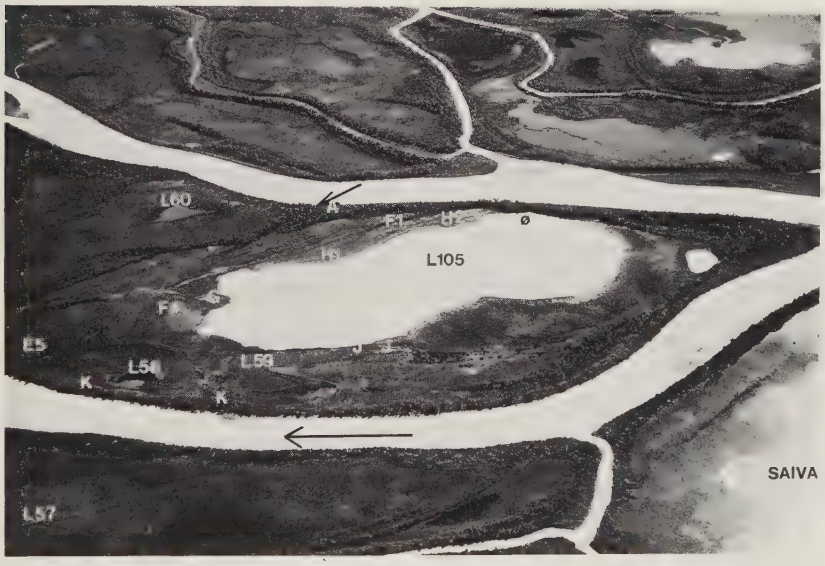


Fig. 68. Lagoon 105 from the north (Skerfe) in 1974. Water-level in Lake Laitaure=152 cm, the water-level in the lagoon was 220 cm. The meander scroll (area J) in Fig. 66 is only one in a row from the River Nuourtätno towards the lagoon. The small open water area in the western part of the interlevee basin is deep (1.5 m), in places edged by a low row of willows. There have not been any visible changes around the lagoon since 1904. The lagoon is probably equivalent to lagoon 89 (see Fig. 53). For explanation of the markings see section 5.2.6.3.

5.2.6 Lagoon 105

The lagoon is situated immediately behind the bifurcation of the Kuoutätno and the Nuourtätno and is delimited to the east by the former distributary A (see Figs. 4 and 66) and its levees. The western border, which is highly influenced by windblown material, is about 5 m high. It may have a till core. The northern and southern borders consist of rather low but well-developed levees. Within the basin there are many small lagoons (58, 59, 64, 65, 66 and 67). The development of vegetation in lagoons 58 and 59 is treated at the end of this section.

5.2.6.1. Hydrology

The channel connecting lagoon 105 with the Nuourtätno is closed, the high water threshold being situated at the connection with the Nuourtätno. In 1904 the channel was open at both ends but had the same extension as in 1974. Under normal circumstances this channel would have been closed earlier than in 1904 but formerly when the swamp vegetation was harvested, some of the lagoon channels were dredged to lower the water level at harvesting time or to create possibilities to bring a boat into the lagoon (see section 2.5). This lagoon channel has been dredged (pers.

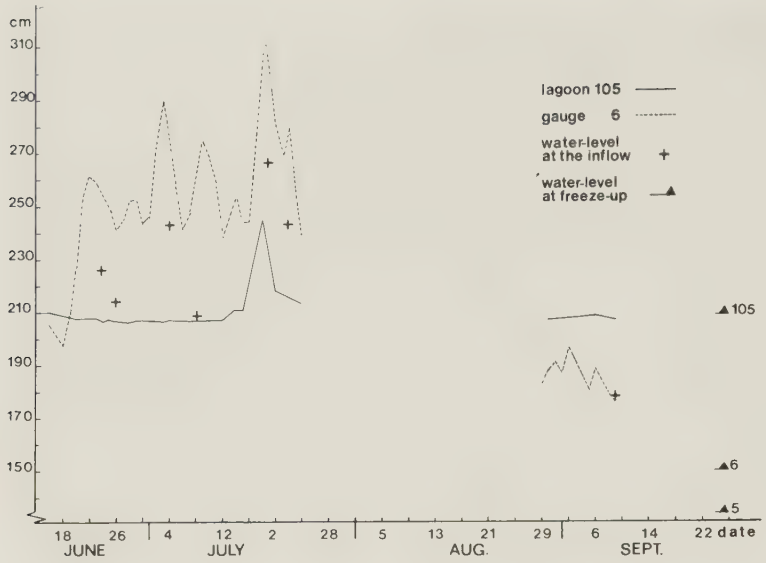


Fig. 69. Daily water-level variation in 1973 in lagoon 105 compared with that of Kuoutätno 6 and few measurements at the channel-distributary junction. The water-levels at freeze-up in the lagoons are also shown. 150 cm is equivalent to 494.8 m above M.S.L.

comm. W. Ländta) but not since 1940 when the harvesting was discontinued. After the dredging ended the channel became closed at the distributary connection.

The extension of the channel is due to its position along a convex bend of the distributary which is also the reason for the development of the low water threshold at the distributary connection. The original low-water threshold may, however, have been situated at the connection with the lagoon. The low-water threshold deciding the water-level today is probably situated somewhere along the degenerating levees of distributary A. The channel has been levelled (see Fig. 64), the threshold was found to be about 40 cm above the water-level in the lagoon.

The water-level variation in the lagoon is very small, only about 5 cm, extreme high-water excluded (see Fig. 69). This very stable water-level was also recorded in 1972. There is no influence at all of the water-level variation in the Kuoutätno, the latter measured at water-level gauge No. 6. The small rise of the water-level on 15–16 July 1973 was due to heavy rainfall. During the extreme high-water in 1973 the whole basin was filled and the water streamed in an easterly direction passing the levees both along the Nuourtätno and the Kuoutätno, the channel then working as an outflow. However, after a week the water-level was back to normal.

At freeze-up the water-level at gauge No. 6 was about 60 cm below the water-level in the lagoon. The water reaches the birch-covered areas around the lagoon at freeze-up.

A few measurements of the water-level in the Nuourtätno at the outflow of the channel have been made. These measurements show that the high threshold almost always prevents the water from passing backwards into the channel.

5.2.6.2. Description of the vegetation in and around the lagoon in 1974

Open water vegetation: Potamogeton alpinus – Sparganium sp. vegetation is found everywhere but *Sparganium minimum* covers the bottom here and there. *Drepanocladus trichophyllus* and *Calliergon giganteum* are also found but never fill the whole water volume.

Swamp vegetation: Along extensive waterward stretches the reedswamp is dominated by *Carex rostrata* without a rhizome blanket. The interjacent swamp subzone is usually a mixed sedge swamp dominated by *C. rostrata* often with a thick sod. The swamp close to the levees has the same composition as the interjacent swamp.

Willow vegetation: Along all borders except the eastern one the willow zone is very narrow, one to three shrubs broad. The field-layer vegetation is dominated by swamp species, mainly *Carex rostrata, C. aquatilis, C. juncella, C. canescens* and *Equisetum fluviatile*. The latter species also invades the patches of open water formed between the shrubs. The willow vegetation in the eastern part is described in section 5.2.5.3.

5.2.6.3. *Development of vegetation and land from 1904 to 1974*

The development of the vegetation is shown in Fig. 65. For location of the areas described see Figs. 66, 67 and 68.

Area A: Constitutes the former delta distributary.

In 1904 the delta distributary was totally cut off from the Kuoutätno. The two birch-covered levee areas F1 and F2 bordered a comparatively flat central part, the former distributary, which was covered by willow and swamp vegetation. There was only one area with open water. In 1974 many areas of open water occur, the willow vegetation is dead or dying, as are the birches. Area A could be compared with the bifurcation of the Kuoutätno east of lagoon 69 (see Fig. 40).

Area B: Constitutes separated areas which in 1904 were covered by swamp vegetation but in 1974 by open water, e.g. lagoons 64, 65, 66 and 67.

In 1904 the swamp-covered areas were bordered by willow vegetation. In 1974 the bottom of the lagoons is covered by dead *Carex* clumps overgrown by thick carpets of *Drepanocladus trichophyllus* and *Calliergon giganteum*. The reedswamp is formed by *Carex rostrata* rooted in the bottom and followed shoreward by *C. aquatilis* very frequently on a floating sod. *Potamogeton alpinus – Sparganium* sp. vegetation is also common.

Area C: In 1904 there was open water in this area. In 1974 it is a part of lagoon 65, the only lagoon where the bottom is not covered by tussocks.

Area E: Covered by willow vegetation in 1904.

Area E1. Broad willow-covered area downstream of the distributary A. In 1904 the willows seemed vital and possibly extended into the swamp of lagoon 60. In 1974 the part of the willow zone closest to the lagoon has totally disappeared, and in the interjacent part the willows are dying. The vitality of the shrubs is from 3 to 1.

Areas E2, E3 and E4. Constitute the former distributary. In 1974 the willows in these areas are dead except very close to the birch-covered levees. White sticks of *Salix* show the former distribution. The ground is covered by their roots and stems and, depending on position, there is either an *Eriophorum angustifolium* swamp or a mixed sedge swamp in these formerly willow-covered areas.

Area E5. Situated between the distributary A and the lagoon channel. The sedimentation pattern in this area was probably very complicated as water may have reached the area from opposite directions. In 1904 the area consisted of a mosaic of willow shrub and open probably swamp-covered, patches. The willow shrubs seem lower than in other areas around the lagoon. In 1974 nothing is left of the willow shrubs above the swamp level.

Area F: Constitutes the slightly higher levee crests framing the former distributary A.

Area F1. Constitutes the upstream levee which extends almost across the basin but becomes lower and lower and less well-developed with the distance to the Kuoutätno. In 1904 there was a single row of birches bordered by a rather wide willow zone. In 1974 only the birches in the southern part close to the Kuoutätno are alive while all the others are dead or dying. The willows are also dying. The ground is usually kept together by a thick moss carpet dominated by *Polytrichum commune* and *P. juniperinum*.

Areas F2 and F3. Constitute the eastern levee ridge of distributary A, which passes across the whole basin.

Area F2. The southern part of the levee ridge. In 1904 the area was covered by birches with willows in between. In 1974 the birches in the area are still alive but the field-layer vegetation over large areas is dominated by swamp species. Areas can be found where *Vaccinium myrtillus, Juniperus communis* and *Equisetum fluviatile* grow in the same 0.25 m^2 square. Passing towards area F3 the vitality of the birches decreases and some are dead.

Area F3. The northern part of the levee ridge. In 1904 only single birches grew among the willows. In 1974 birches grow over a much larger area than in 1904 but their vitality is low. The field layer is dominated by swamp species and there are often patches of open water at the levee ridge.

Area F4. In 1904 scattered birches occurred among the willow shrubs on this narrow levee, but in 1974 nothing is left of the shrubs.

Area F5. Situated at the connection between the Nuourtätno and distributary A. In 1904 there was birch vegetation. In 1974 the birches are still alive but the field-layer vegetation resembles swamp vegetation except on the highest spots.

Area G: Possibly a former in-and-outflow of lagoon 105. If a comparison is made with lagoon 69, it is the channel directed in the stream direction which is shallowest and probably will be closed first.

In 1904 it looks as if there were two former channels overgrown by swamp vegetation and bordered by willow-covered levees. In 1974 the whole area is covered by swamp vegetation.

Area H: Comprises the reedswamp and interjacent swamp subzone situated in the southeastern part of the lagoon in 1904.

Area H1. In 1904 this area was covered by apparently young and not very dense swamp vegetation

bordered towards the lagoon by a willow-covered ridge. In 1974 no willow shrubs can be recorded and the area is covered by water. The part closer to the shore is covered by swamp vegetation dominated by *Carex rostrata*.

Area H2. In 1904 this area was covered by swamp vegetation with a central circular open water area. In 1974 swamp vegetation covers the whole area except for the former reedswamp which now is water-covered.

Area K: Two triangular areas along the Nuourtätno. In 1904 the areas were covered by willow shrubs but in 1974 all shrubs are dead.

Lagoon 58

The lagoon was probably formed as a consequence of shelter from sedimentation by the levees of the channel from the Nuourtätno, or it may be a lagoon formed from swamp vegetation already in 1904, as a consequence of a low water threshold.

In 1904 the water-covered area was quite small and surrounded by seemingly homogeneous swamp vegetation. In 1974 the water-covered area has enlarged downstream along the channel. Open water exists in the swamp. In the lagoon large clumps of *Carex aquatilis* are frequent. *Carex rostrata* dominates the reedswamp. *Calliergon giganteum* and *Drepanocladus trichophyllus* are found in the lagoon together with *Potamogeton alpinus – Sparganium* sp. vegetation. The part closest to the lagoon of the narrow willow zone along Nuourtätno contains dying shrubs.

Lagoon 59

The lagoon is separated from lagoon 105 by area J, probably a former point bar along the Nuourtätno, the lagoon thus being a former meander scroll depression. Fig. 65 shows that there are many meander scrolls and depressions between area J and the Nuourtätno.

In 1904 area J was covered by low willow shrubs. The swamp vegetation around the lagoon was possibly discontinuous. In 1974 the shrubs along area J are dying and swamp vegetation prevails. The area of the lagoon has not enlarged much but the reedswamp is now disintegrating. The bottom of the lagoon is covered by a 40 cm thick layer of *Drepanocladus trichophyllus – Calliergon giganteum* vegetation.

6. Stratification of lagoon sediments

The stratification and composition of lagoon sediments have been studied in a few lagoons. The aim was to try to verify some steps in the succession and a lagoon was chosen from which photographical evidence of different developments was available, the choice depending on the disappearance of the swamp vegetation over a large area and the development of a miniature delta and a threshold in lagoon 36 (see Figs. 61 and 62).

6.1. Methods and material

The bottom sediments were sampled from the ice in April 1973. A Livingstone sampler with a tube length of 125 cm and a tube diametre of 40 mm was used. The very deep samples "110", "west", and "40" were taken in three parts from selected levels after drilling away the overlying sediments. The sediment cores were either transported to the camp in the tubes or, as generally the case, were measured and briefly investigated in the field and then transported in boxes. A detailed description of colour, grain size, and plant materials at different levels in the cores was made at the camp at Aktse. In Uppsala some levels were investigated for macroscopic fossiles. No corrections have been made for the expansion of the water when freezing into ice, or the possible expansion or compaction of thick sedge sods following freezing. As the sampling tube has no sharp edges, there might have been some compaction of recent or buried sedge sod on sampling, for which no corrections have been made. However, in several cases the top sod was removed by the ice drill as it was impossible to get the sampling tube through it.

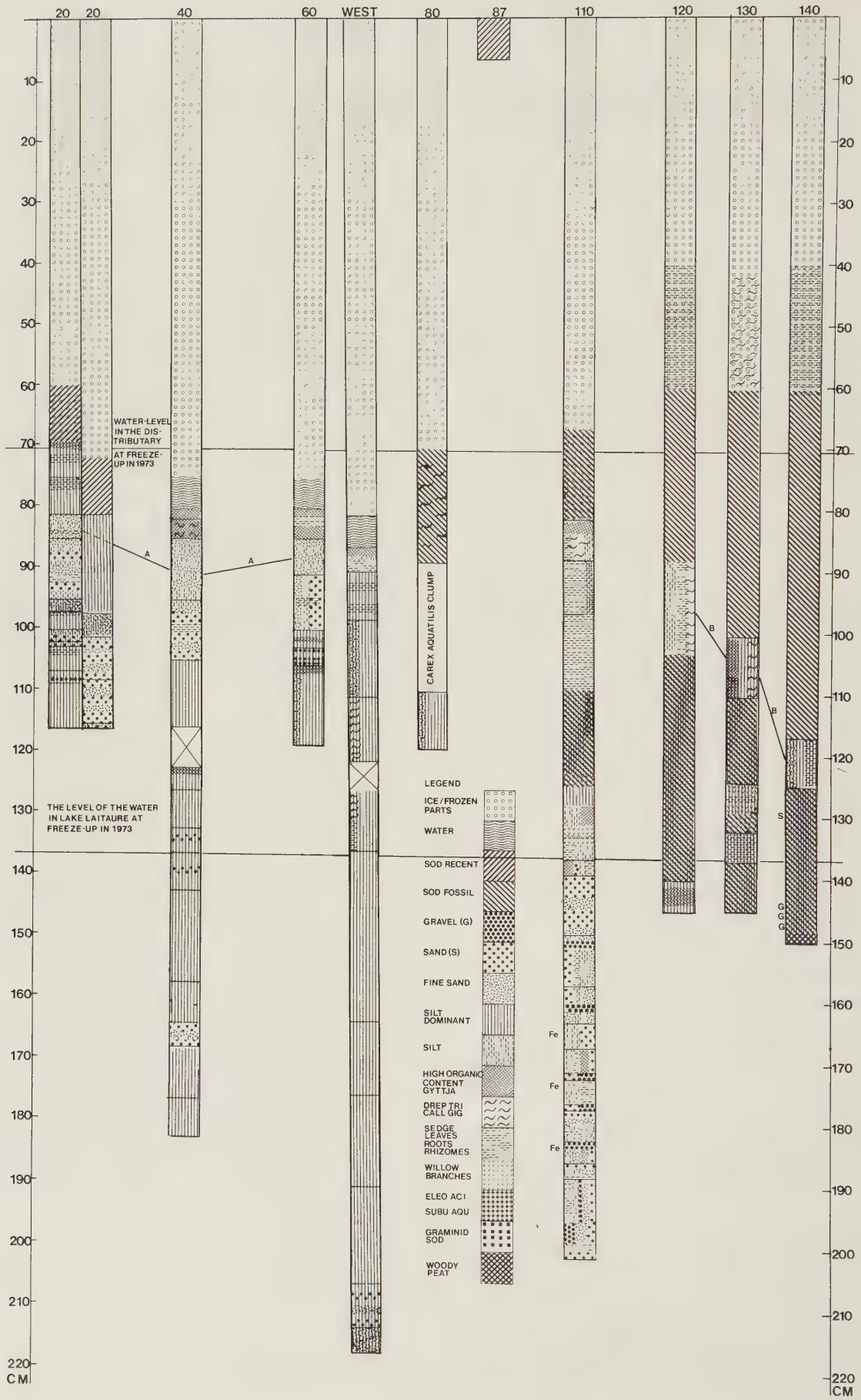
The sediments were sampled at intervals of 10 or 20 m along a transect crossing the lagoon (see Figs. 61 and 62). One sample called "west" was also taken in what has been found during summer investigations to be the deepest part of the lagoon. The first sample was taken at 20 m from the willow zone of the channel levee in the reedswamp, thus with recent swamp vegetation. Samples at 40 and 60 m were taken in an area which probably always has been covered by open water. The sample at 80 m was taken rather close to a former levee (area B3; Fig. 61) and has also probably always been covered by open water. At 87 m *Carex aquatilis* and small willow shrubs reached above the ice level as remnants of the formerly willow-covered levee ridge which is now dominated by sedges. At 90 m there was 30 cm of clear ice followed by a recent sedge sod. Samples at 110, 120, 130 and 140 metres were taken in area D1 (Figs. 61 and 62) which in 1922 was covered by swamp vegetation, though in 1974 by open water with scattered standing clumps of *Carex aquatilis*.

6.2. Results and discussion

Fig. 70 shows the main stratification, although somewhat simplified, of the lagoon sediments along the transect. The depth of the ice and the unfrozen water in the different samples, and thus the water depth above the sampling points is easily seen from Fig. 70.

Sample 20: The recent sod was about 10 cm thick and the water depth of 60 cm is very often the depth limit for *Carex aquatilis*. In 1971 there was swamp vegetation for another 2 or 3 metres out in the lagoon which consequently has died off. Underneath the sod was a silt-dominated layer with a high content of plant material but without coarse mineral sediment. The part between 83 and 103 cm was layered with coarse and fine sediments. The coarser sediments were probably deposited at high water with enough current for bedload transportation, and the finer from suspended load at lower water-levels. The bottom of the sample was dominated by silt, probably deposited before the channel had reached the area, thus on a lagoon bottom. The homogeneity and coarseness of the material resemble what is found at greater depth in open lagoons far from any levee. In this horizon there were a few distinct layers of remnants of *Eleocharis acicularis – Subularia aquatica* vegetation. This kind of vegetation could then, in the succession, be followed by swamp vegetation (Dahlskog 1974 p. 3:2).

Samples 40 and 60: These ones and sample "west" are the only samples with unfrozen water between the ice and the sediments. The water had a high concentration of H_2S except for sample "west" where chironomids were found. Both samples show the same stratification. The top 5 cm were loose and highly organic with large amounts of *Drepanocladus trichophyllus* and


20
20
40
60
WEST
80
87
110
120
130
140
WATER-LEVEL IN THE DIS-TRIBUTARY AT FREEZE-UP IN 1973
A
A
THE LEVEL OF THE WATER IN LAKE LAITAURE AT FREEZE-UP IN 1973
CAREX AQUATILIS CLUMP
B
B
S
G
G
G
Fe
Fe
Fe
LEGEND
ICE / FROZEN PARTS
WATER
SOD RECENT
SOD FOSSIL
GRAVEL (G)
SAND (S)
FINE SAND
SILT DOMINANT
SILT
HIGH ORGANIC CONTENT GYTTJA
DREP TRI CALL GIG
SEDGE LEAVES ROOTS RHIZOMES
WILLOW BRANCHES
ELEO ACI
SUBU AQU
GRAMINID SOD
WOODY PEAT
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
CM

Calliergon giganteum and pieces of sedges. From 85 to about 100 cm the samples were layered. The coarse material probably reached the area when the levees were flooded and the fine material is there as a result of deposition of suspended load in the lagoon. The homogeneous horizon between 105 and about 115 cm dominated by silt probably corresponds to the similar horizon in the sample at 20 m. In the sample at 60 m there was a distinct layer of remnants of *Eleocharis acicularis – Subularia aquatica* vegetation which could have covered the bottom although at a lower water depth than today (see Fig. 22). In sample 40, from 125 to 185 cm, the sediment was totally dominated by silt but with differences in colour and with a few layers of coarser material. This part was probably deposited mainly as suspended load when the lagoon was open (see also sample "west").

Sample "west": The top 5 cm was loose and had a high content of organic matter. From 90 to 205 cm the sediment was totally dominated by silt, the uppermost 45 cm containing large amounts of *Drepanocladus trichophyllus, Calliergon giganteum* and leaves of sedges together with unidentified plant material. Between about 100 and 112 cm there was some fine sand, probably deposited at the time when the lagoon channel was directed towards the sample area. The coarse sediment at the bottom of the sample could have been deposited as a foreset bed.

Sample 80: The top 20 cm consisted of a mixture of leaves of *Carex aquatilis, Drepanocladus trichophyllus* and *Calliergon giganteum*. At 90 cm there was a dead root-and-rhizome clump of *Carex aquatilis*. It was necessary to use the ice drill to get through the rhizome clump as well as to collect a sample of the minerogeneous sediment below it. These sediments were very firmly packed and the Livingstone sampler could not penetrate through them. The top sediments consisted of almost pure silt with 1 to 5 % of fine sand. The very hard packing resembles what is found in deep-pools along levees in active distributaries (cf. 87 metres).

Sample 110: The profile was dominated by *Carex* remnants down to 124 cm. The top 15 cm consisted of a dead *Carex* sod. The next 6 cm was very loose with a large amount of *Drepanocladus trichophyllus* and *Calliergon giganteum* followed by a layer with *Carex* stolons embedded in silt and fine sand and then a layer with roots and rhizomes. From 110 to 124 cm there was a new sedge sod with layers of fine sand. From 124 to 126 cm there was a firmly packed sedge peat with willow sticks mixed with silt and fine sand. From 126 to 138 cm there was a high content of organic material with many layers of silt and branches of *Salix* which without sharp boundaries mixed with the underlying more minerogenic part. From 138 to 200 cm minerogenic depositions dominated, often in clearly visible layers. Coarse material as gravel and sand, usually in distinct bands, was mixed with silt and fine sand. There was also distinct layers with plant material and three distinct layers with iron ochre. The most interesting feature was the graminid sod found 164 cm below the ice. In the lower part of the sample the coarseness and layering of the sediments resemble what is found in young sandbars.

The possible history of the area at point 110 is as follows: The area of the sample was probably a sandbar sheltered from streaming water by the above-mentioned levee ridge (see Fig. 61, area B3). Thus it was occasionally reached by coarser material but also subjected to suspended load in calm water. The bar was probably covered by pioneer vegetation which developed into a mixed graminid swamp with or without scattered willow shrubs. Following a raised water-level the mixed graminid swamp developed into a sedge swamp building up a thick sod. The swamp vegetation was then drowned.

Samples 120, 130 and 140: The three samples show the same general stratification. Some plant residues were found in the lower part of the ice. Below this followed a sedge sod with a low content of minerogenous sediments. In sample 140 this sod was dominated by *Carex rostrata* at least in the upper part. This was followed by a highly organic silt layer on top of a silty sod. The bottom parts of the cores were, however, different. In sample 120 the bottom part was dominated by silt with

Fig. 70. Stratification of the sediments along a transect crossing lagoon 36 where large areas of swamp vegetation have disappeared during the documented period (see Fig. 62). The stratification in the cores is greatly simplified. The layering in the different zones distinguished is illustrated with horisontal lines when there is a distinct layering and with vertical lines where there is a mixture of the materials or where the layers are very thin and too many to be represented. The colour of the zones is not given except when there is a very high content of iron-ochre which is marked with Fe. A and B indicate layers deposited at the same time with the same composition and stratification. The water-level at freeze-up in the distributary at the channel-distributary junction in 1973 is indicated and approximates the water-level in the lagoon if it was without thresholds. The water-level in Lake Laitaure at freeze-up of the lagoons in 1973 is given to estimate the development of the lagoon from the formation as a bay to Lake Laitaure.

Note especially the thick fossile sods in samples 120–140 and the stratification in the lower part of sample 110 which resembles that found on the large flat bars at the delta front today. Fossile sods do not produce shoots and are usually covered by water or sediments.

a high organic content. In sample 130 there was a silt-dominated layer with a high content of sticks of *Salix* from 124 to 128 cm as also in the underlying sod. The bottom of the sample consisted of a sedge sod with a high silt content. In sample 140 the bottom sod had distinct layers of both sand and gravel. At the extreme bottom in the same sample there was a layer of compact woody peat.

Today there is swamp vegetation in the area, and consequently even the top sod could be referred to as sub-fossil. The difference in thickness of the top sod might be a consequence of differences in the original depth of the basin. The silty organic layer underneath the top sod could originate from a high water period or could represent the boundary between firm sediment and a floating swamp. The high percentage of silt in the lower part of the sod suggests frequent submersion with turbid water, thus in an open lagoon.

The *Salix* sticks found in sample 130 were situated at the same level as in sample 110. This does not necessarily impose willow vegetation in the area. The resolution in the photo from 1922 is not good enough to allow detection of low willows. There are however irregularities resembling willow shrubs indicating that a part of the area might have been covered by vegetation typical for the swamp-willow subzone.

6.3. Summary of the development of lagoon 36

After the delta front reached and passed the area there has been a gradual build-up of the ground. The geomorphological history of areas D1 and B3 (see Figs. 61 and 62) is probably very complicated as there are many meander scrolls and levees in the area. It might be presumed that area D1 was silted up earlier than the part now covered by open water and the part occupied by the lagoon channel.

The water-level in the lagoon, when being a bay of Lake Laitaure and thus situated at the delta front, could be roughly estimated as being around 140 cm below the water-level at freeze-up today (see Fig. 70), the water-level in Lake Laitaure in 1973 being about 76 cm at freeze-up in the lagoons. These calculations thus indicate that the areas of samples 120, 130 and 140 should have been covered by frequently submerged swamp vegetation, and possibly by scattered willows. This is quite feasible with regard to the water-level and its variation in an open bay. The area of sample 110 could then have been a pioneer-colonized bar. The vegetation in the area then developed into swamp vegetation. The very distinct graminid sod would then have been situated 20 cm below the lowest water-level but a compaction of 20–30 cm of the sediments during perhaps 1000 years cannot be precluded.

When the lagoon was still a bay the areas of samples 20, 40, 60, 80 and sample "west" were open water which received loading from a distributary or from Lake Laitaure and the areas were slowly silted up. As the delta gradually filled up the basin downstream of the actual lagoon, the water-level rised continuously and evidently the accumulation of organic and inorganic material kept up with the rise in water-level in samples 110, 120, 130 and 140.

Today the water-level at freeze-up lies 70 cm above the level in the nearest distributary. It could then be presumed that at the time when the lagoon was totally open a water-level 70 cm below the present level might have existed at freeze-up. As there were sandbars at the mouth of the miniature delta in 1904 at least a low threshold has to be presumed. The state with no low-water threshold must then be still older.

Assumption of a water-level 70 cm lower than today gives the following interpretation: The channel had not reached the area of sample 20 and with a water depth of 40 cm (the depth to the horizon with *Eleocharis acicularis – Subularia aquatica* remnants) the bottom might have been covered by *Eleocharis acicularis – Subularia aquatica* vegetation. Then the channel between the area and the distributary was developed and the coarse and fine sediments were deposited from overbank flow. The areas of samples 110, 120, 130 and 140 were at the time covered by swamp vegetation. In 1922 the actual areas were still covered by swamp vegetation but as the threshold grew between 1922 and some time in the forties the accumulation of organic matter could not keep up with the rise in the water-level. The depth of the water became too great for the sedges and the swamp started to disintegrate, leaving rhizome clumps of *Carex aquatilis*.

7. Retrogressive successions in three interlevee basins

7.1. Development of lagoon 84 from 1899 to 1974; die-off of willow shrubs in less than 50 years

The development of lagoon 84 from 1899 to 1974 has been chosen as an example of dying-off of willow shrubs under a relatively short period, in an area close to the delta front. The lagoon has passed from the state of an open bay to a closed lagoon with a comparably stable and raised water-level compared with the distributary passing it. The development is shown in Fig. 71.

In 1899 (see Fig. 73) this lagoon was an open bay. Along the Nuourtätno the levee was covered by willow shrubs and the willow zone was comparatively broad. The western levee was very narrow but covered by willow shrubs. The southeastern part of the lagoon was connected with Lake Laitaure. The reedswamp was probably of a pioneer type with rather sparsely distributed swamp species.

In 1904 the southeastern bar had enlarged towards Lake Laitaure which also accounts for the eastern border of the lagoon. Pioneer vegetation dominated these new areas.

In 1922 (see Fig. 74) the bay had developed into a lagoon and a channel connected the open water of the lagoon with the distributary. A miniature delta was under formation as there is a sandbar to be seen at the mouth of the channel. The lagoon area was well-defined and surrounded by swamp vegetation. The broad willow zone along the Nuourtätno had almost the same extension as in 1904, although it may have expanded a little. Along the western levee the willow zone was still as narrow as in 1904. It is not possible to detect any

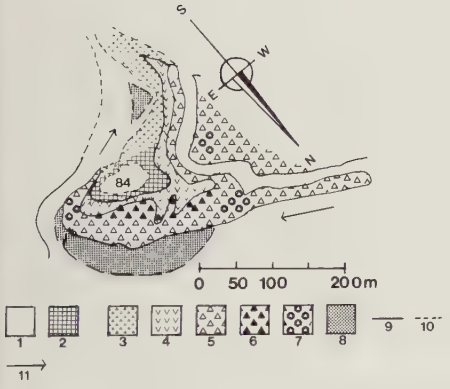


Fig. 71. Development of land and vegetation around lagoon 84 from 1899 to 1974. 1. Open water during the whole period; 2. Open water developed to swamp vegetation; 3. Open water developed to willow vegetation; 4. Unchanged swamp vegetation and pioneer vegetation developed to swamp vegetation; 5. Willow shrub vegetation with unchanged good vitality; 6. Willow vegetation which has died during the period or is dying and invaded by swamp vegetation; 7. Establishment of birches in willow vegetation during the period; 8. Sand bar in 1971; 9. Boundary between land and open water in 1899; 10. Boundary between land and open water developed after 1899, most of the land-forms being developed already in 1922; 11. Direction of current. Long hatched line see Fig. 3.

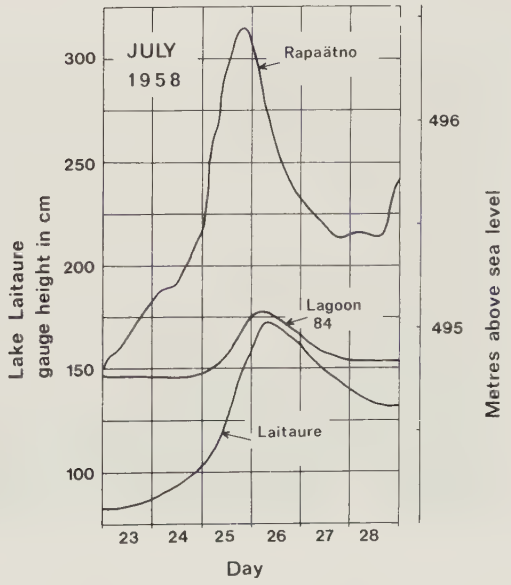


Fig. 72. Water stage in the River Rapaätno at the proximal part of the Laitaure delta, in lagoon 84 and in Lake Laitaure at the delta front during July 23–28, 1958 (from Axelsson 1967).

Fig. 73. Lagoon 84 from the north (Skerfe) in 1899. The lagoon was a small bay of Lake Laitaure, the willow vegetation was probably low. The eastern border was very narrow and has hardly become broader during the 70 years documented. Probably relatively high water-level.

Fig. 74. Lagoon 84 from the north (Skerfe) in 1922. The open bay of 1899 has now developed into a lagoon with channel connection to the distributary passing east of the lagoon. The willow vegetation in the northern part of the interlevee basin was probably a high willow vegetation.

willow vegetation along the eastern lagoon border but small shrubs could very well have developed since 1904.

In 1954 (see Fig. 16) there was no channel connecting the lagoon with the distributary. Valter Axelsson (1967) measured the water-level variation in this lagoon in 1958. As can be seen in Fig. 72, the water-level in the lagoon did not start to rise until the water-level passed the levee crest. The water-level then after the flooding again became comparatively stable. This indicates that there was no open connection to the distributary. There was swamp vegetation around the open water area. Since 1922 the northern willow zone had grown denser and might have expanded a little. A few birches appeared in the western part of this area. The levee along the western border was still very narrow. Small shrubs appeared along the northern part of the eastern levee.

In 1965 (see Fig. 17) the open water area was slightly larger than in 1954 (see Fig. 16). Comparisons between 1954 and 1965 show a regression of the northern broad willow zone. Areas with open water are also to be seen at the border between the willow zone and the swamp zone. The eastern narrow levee was covered in its whole length by small willow shrubs.

In 1971 (see Fig. 75) the water area has enlarged slightly, the reedswamp is tussocked and there are clumps of *Carex aquatilis* in the lagoon. The reedswamp and interjacent swamp is dominated by *C.*

Fig. 75. Lagoon 84 from the north (Skerfe) in 17 July, 1971. Water-level in Lake Laitaure = 107 cm. The channel is closed and the water area is enlarged compared with the water area in 1954. The willows in area A are dying.

aquatilis. *Potamogeton alpinus* – *Sparganium* sp. vegetation dominates in the lagoon but *Drepanocladus trichophyllus* – *Calliergon giganteum* can also be found in some parts. The willow zone along the Nuourtätno is still narrower than in 1966 and a large area is covered by dead or dying willows. The low-water threshold is situated in the swamp and there are remnants of the channel at the connection with the distributary where excess water is seen coming out from the lagoon in a 2–3 cm broad 0.5 cm deep rill.

In 1974 the lagoon area has enlarged over the former miniature delta. The reedswamp is tussocky and there are large areas with dying willows.

7.2. Development of lagoon 50 from 1904 to 1974

The development in lagoon 50 provides an example of disintegration of swamp vegetation in 4 years and also an example of extension of the swamp zone in a lagoon with only channel connection to streaming water.

There are many examples of reedswamps having disintegrated since 1904 but there are not many where the swamp vegetation has grown into the lagoon and then disintegrated and where the reedswamp has disintegrated in 4 years. The disintegration usually starts in the western tip of a lagoon. Particularly two facts indicate that the western end of a lagoon might be different from the rest: there are comparatively low-lying areas which were sheltered from loading at an early stage, and the possibility for development of a floating reedswamp is better as wave action is less frequent than along the other shores. The development has been drawn schematically (Fig. 76) and is also shown by photos (Figs. 77, 78, 79 and 80).

7.2.1. Development of the swamp zone

From 1904 to 1922 the swamp zone expanded in the western part of the basin and a small part of the open

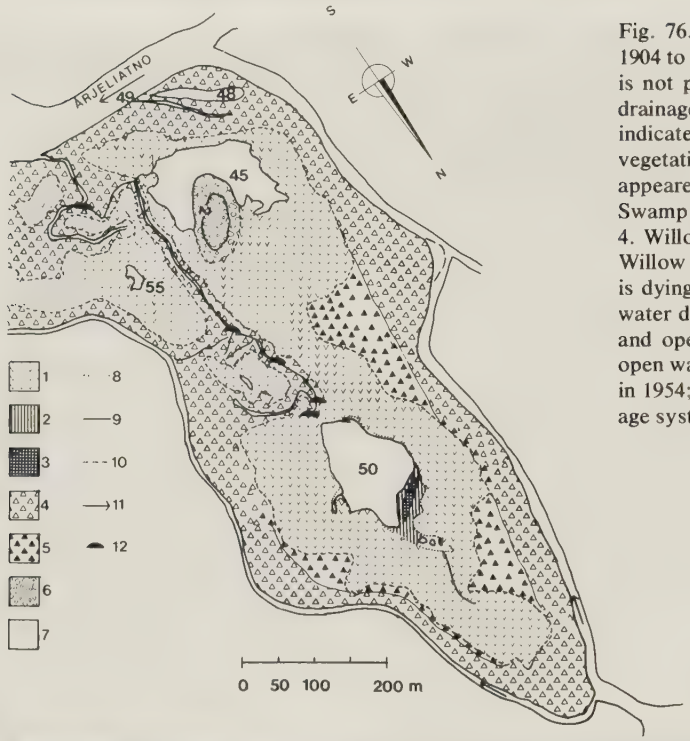


Fig. 76. Development of vegetation around lagoon 50 from 1904 to 1974. The vegetational development around lagoon 45 is not properly shown. Birch vegetation is not shown. The drainage system from lagoon 50 to the River Årjeliätno is indicated and the thresholds of 1972 is marked. 1. Swamp vegetation unchanged; 2. Swamp vegetation which disappeared between 1970 and 1974 (most of it in 1973); 3. Swamp vegetation which disappeared between 1954 and 1970; 4. Willow shrub vegetation with unchanged good vitality; 5. Willow shrub vegetation which has died during the period or is dying and invaded by swamp vegetation; 6. Till; 7. Open water during the whole period; 8. Boundary between swamp and open water in 1904; 9. Boundary between swamp and open water in 1954; 10. Boundary between swamp and willow in 1954; 11. Direction of current; 12. Thresholds in the drainage system of lagoon 50 in 1972.

Fig. 77. Lagoon 50 from the south (Tjakkeli) in 1904. The channel leading from the lagoon was open at least in the downstream part. There might, however, have been a threshold at the connection between the channel and the lagoon. There was continuous swamp between lagoon 50 and lagoon 45, the latter at the time having an open channel connection to the River Årjeliätno. For explanation of the markings see section 7.2.

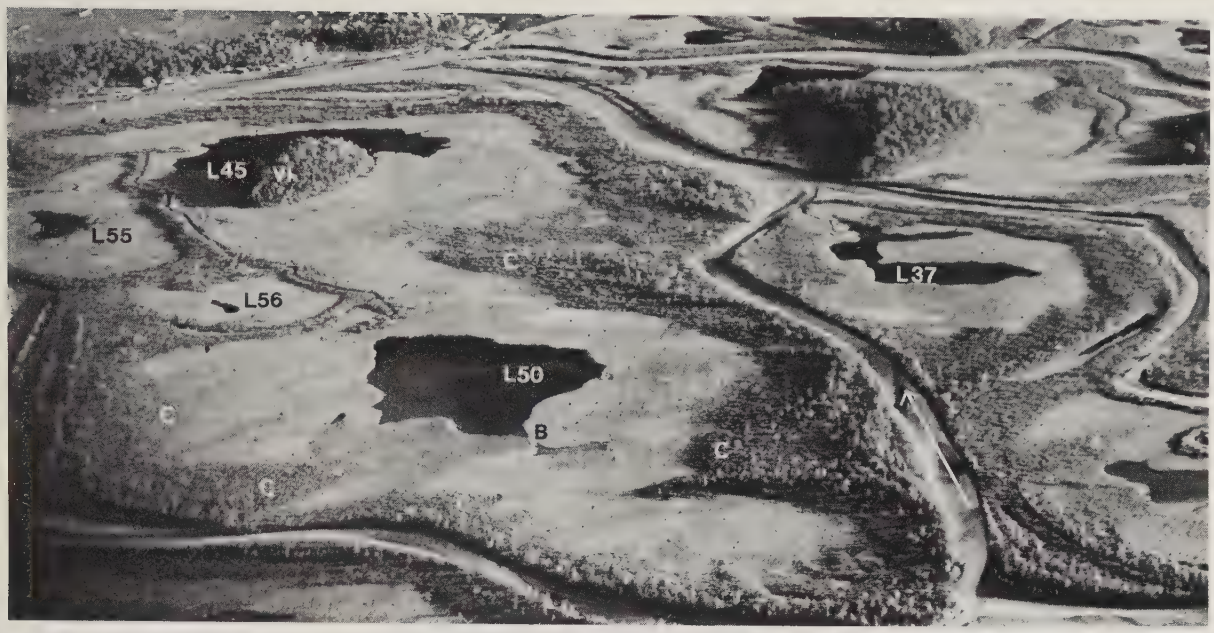


Fig. 78. Lagoon 50 from the north (Skerfe) in 1922. At the channel-lagoon junction there was swamp vegetation but the channel from lagoon 45 could still have been open. The most lagoonward shrubs in the areas marked C could have had a lowered vitality in 1922. Area B was developed between 1904 and 1922.

water area was closed off. The swamp zone might have expanded by an extension of the sedge sod over the open water area or by *Carex rostrata* specimens rooted in the bottom. In 1972 the vegetation in the most lagoonward part of this area is a *C. rostrata* reedswamp followed shoreward by a *C. aquatilis* swamp on a floating sod.

Between 1922 and 1954 the western part of the lagoon was reduced by swamp vegetation. The area where the swamp vegetation was comparatively young is easily seen on the air-photo from 1954. This swamp vegetation was probably composed of *Carex rostrata* rooted in the bottom vegetation with a rather thin sod of *C. aquatilis* in between. This assumption is based on the fact that the structure and colour was the same as in lagoons 51 and 53 where *C. rostrata* rooted in the bottom forms the reedswamp and is then followed by a more or less floating *C. aquatilis* – *C. rostrata* interjacent swamp.

Between 1954 and 1965 the extent of the swamp vegetation was almost unchanged but shoreward from the reedswamp there was water above the swamp level in a narrow zone.

Between 1965 and 1971 the area where water could be seen developed into a tussocked swamp fringed towards the lagoon by a homogeneous swamp.

In 1972 the open water area inside the reedswamp is larger. In 1973 the reedswamp has receded almost to the extension which it had in 1904. There are structures in the open area of the lagoon which resemble, and can be remnants of, the former reedswamp. In 1974 there are only a few clumps of *Carex* left of the swamp zone developed between 1904 and 1954.

7.2.2. Development of the willow zone

In 1922 the willow zone seemed healthy and vital all around the lagoon.

In 1954 the parts of the willow zone closest to the lagoon had disappeared totally and in the shoreward part of the zone the willows were dying. There was open water at the border to the denser willow zone.

In 1974 the extension of the willow zone appears to have become still further reduced and the willow shrubs are only vital along the levees close to the active distributaries.

7.2.3. Development of the water regime in the basin

The drainage system of lagoon 50 has been very complicated and is difficult to interpret (see Fig. 76). It passes from the lagoon and north of lagoon 45 to the Årjeliätno. There has also been a connection to the distributary bordering to the north.

Fig. 79. Lagoon 50 from the north (Skerfe) in 17 July 1971. Water-level in Lake Laitaure=107 cm. Area B has started to disintegrate. Swamp vegetation on a floating sod forms the lagoonward fringe whereas in the area with open patches of open water the sedges grow in the bottom and have died either for some physiological reason or from ice-uplift of the sediment. Compare Figs. 78 and 80. For explanation of the markings see section 7.2.

Fig. 80. Lagoon 50 from the north (Skerfe) in 25 July 1974. Water-level in Lake Laitaure=152 cm. The willow-covered levee which surrounded the lagoonward part of the channel has disappeared; the willows close to the lagoon are dead or dying. In area B a large part of the swamp has disappeared (most of it in 1973). For further explanation see section 7.2.

In 1904 there was probably an open connection between the lagoon and the channel—although narrow and with a low water threshold due to swamp vegetation. However, the rising of the water-level was not high enough to induce a reduction of the vegetation in the basin. The channel to the Årjeliätno was probably open all the way and rather wide and water-filled in the parts close to the distributary.

In 1922 there was still a channel to be seen in the swamp vegetation at the end of the channel. It is impossible to detect any threshold passing along the channel to the Årjeliätno but the connection might well have been closed at some point. It is difficult to interpret the degree of closure of the channel at the lagoon-channel junction.

In 1974 the lagoon is closed off and there are many very high low-water thresholds along it. However, the true threshold for the water-level in lagoon 50 was probably situated in the swamp area between lagoons 50 and 45 and thus lagoon 50 might have become closed when the channel from lagoon 45 silted up.

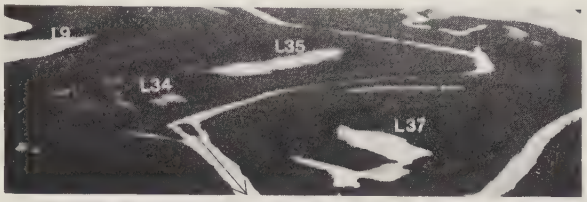


Fig. 81. Lagoons 34 and 35 from the south (Tjakkeli) in 1904. Lagoon 34 had hardly any open water area, only patches between swamp vegetation. For further explanation see section 7.3.

Fig. 82. Lagoons 34 and 35 from the north (Skerfe) in 1922. The areas of open water in lagoon 34 had enlarged compared with 1904. In lagoon 35 the reedswamp had started to disintegrate. For further explanation see section 7.3.

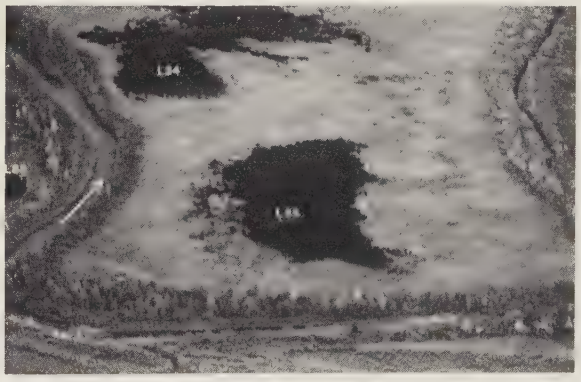


Fig. 83. Lagoons 34 and 35 from the north (Skerfe) in 25 July 1974. Water-level in Lake Laitaure=152 cm. The open water area of lagoon 34 has grown considerably and the reedswamp in lagoon 35 has continued to disintegrate. The bottom of lagoon 34 is covered by clumps of dead sedges. For further explanation see section 7.3.

7.3. Development of lagoons 34 and 35 from 1904 to 1974

The development of lagoons 34 and 35 has been chosen as an example of retrogressive swamp vegetation as it was already developed in 1922.

The structure of the reedswamp is difficult to classify with certainty on photos before 1922 but in at least 4 lagoons, e.g. lagoons 13, 34, 35 and 55, the reedswamp started to disintegrate in 1922. The retrogression is illustrated by the development in lagoons 34 and 35 from 1904 to 1974 (see Figs. 81, 82 and 83). These two lagoons are situated in a comparatively small interlevee basin without till contact.

7.3.1. Development of a low-water threshold

The closure of the basin was probably connected with the closure of the delta distributary bordering the basin to the south. This distributary carried water in 1904 but

whether there was any open contact with the lagoon cannot be determined. In 1922 the distributary was closed off. In 1974 the thresholds at both ends of the distributary are high and covered by low willow vegetation. The levees of the distributary are very low and ill-defined. Consequently at high waters when the distributary still is water-filled, the water passes over the whole levee into the lagoon.

7.3.2. The lagoons

In 1904 the open water area of lagoon 34 was very small and there were tussocks of vegetation in the water-covered areas. Lagoon 35 was comparatively larger but the open water area was surrounded by a tussocky swamp.

In 1922 the patches of open water area of lagoon 34 were much larger than in 1904 and surrounded by a tussocky reedswamp. The open water area of lagoon 35 had not enlarged much but the tussocked reedswamp is easily seen.

In 1954 the open water area of lagoon 34 had grown to about 5 times the size in 1904 (see Fig. 16) and there was no vegetation above the water surface over large areas. The reedswamp was tussocky. Along the eastern border of lagoon 35 the swamp had disintegrated since 1922.

In 1974 the open water area of the lagoon had enlarged still more.

Lagoon 34: There are dead clumps of *Carex* at the bottom of the lagoon and *Carex aquatilis* clumps are common in the water. *Calliergon giganteum* and *Drepanocladus trichophyllus* are commonly found. The reedswamp is dominated by *Carex aquatilis*.

Lagoon 35: This lagoon is deeper than lagoon 34. Dead clumps of *Carex* can be found along the borders of the lagoon and the water volume is filled with *Drepanocladus trichophyllus – Calliergon giganteum* vegetation. The reedswamp is formed by *Carex rostrata* rooted in the bottom but there are lots of *Carex aquatilis* clumps and the interjacent swamp is dominated by *Carex aquatilis*.

7.3.3. The basin and its borders

The levees bordering the two lagoons are comparatively low and narrow and there are only dying willow shrubs to be found along the western levee built up by a now closed delta distributary. The basin is frequently flooded and in the willow zone there is minerogenic sediment below and above a thick layer of *Carex* litter (21 July 1973). The breadth or distribution of the willow zone has not changed since 1922, the western border excepted.

8. Discussion and summing-up of results

From the lagoon description in chapters 5 and 7 it is evident that after the channel leading to a lagoon is closed in one way or another the water-level will fluctuate less than in the delta distributaries, except during conditions at peak flow in the distributaries.

As compared with lagoons with open connections, the closed lagoons therefore have a higher water-level in summertime and a much higher water-level at freeze-up. Accordingly the structure and composition of the vegetation show a differentiation. In closed lagoons tussocky swamps are common and the open water areas frequently become enlarged, while in open lagoons the swamp vegetation is continuous. The willow subzones around closed lagoons are narrow, and there are always areas with dead willows to be found, while in open lagoons the willow zone is comparatively broad, in places reducing the width of the swamp zone.

In Fig. 84 the zonation of the vegetation in lagoons with different water regimes (see section 8.7) has been summarized, and developments possible for different parts of the zonation are indicated. In order to make the six transects comparable the slope of the shore has been equalized. The duration of different water levels in relation to the vegetation zones indicated in Fig. 84 has been measured (e.g. transects 21, 23, and 33 see section 5.1). In Fig. 84 I have used a few unpublished levelled transects along which only the distribution of the major vegetation types and their structure have been recorded. As can be seen, the mean summer water-level is higher in relation to the vegetation zones in a closed lagoon (transects e, f) than in an open one (transects a, b). The water-level at freeze-up is also markedly raised in a closed lagoon as compared with an open lagoon.

8.1. Causes for drowning of vegetation in lagoons

Retrogressive development has been noticed in many deltas in different parts of the world and is usually observed in areas with drowned vegetation. The causes and processes behind the retrogressive development have been judged in different ways.

8.1.1 Raised low-water threshold

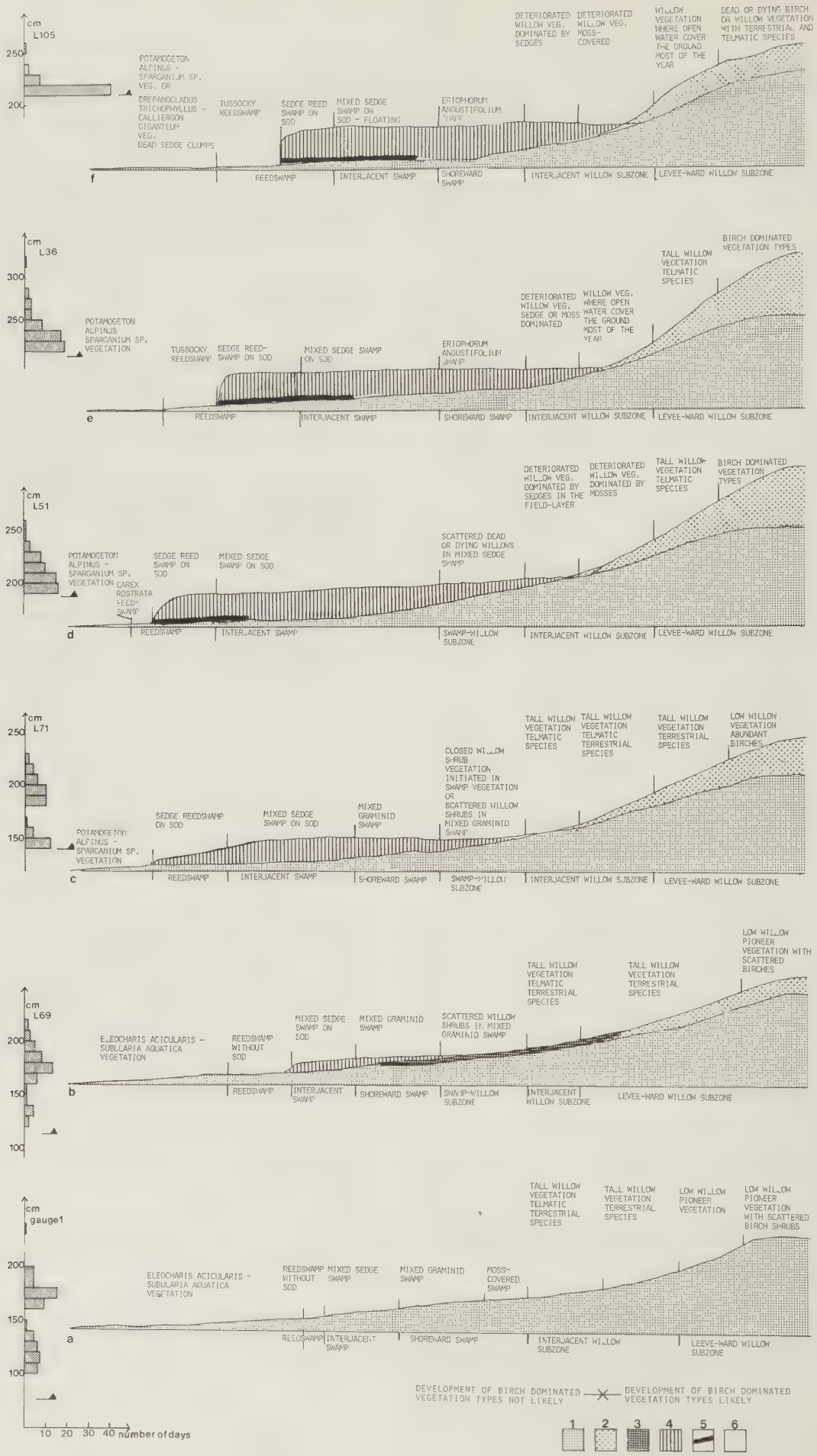
The closed lagoons, especially lagoon 105 (see section 5.2.6), have a water table that is not to any particular extent influenced by the surrounding distributaries, and the water-level is kept high throughout the year. Thus the levees surrounding the basin seem to be impermeable or nearly so (see Fig. 85; an example showing the level of the water in the ground between lagoon 105 and the Nuourtätno). I have only once noticed water coming through a levee; the water-level difference was then 100 cm between the distributary and the lagoon and the levee was very narrow, around 1 m. Kulczyński (1949) also noted the impermeability of the embankments and the comparatively stable and high water-levels in closed-off areas following spring flooding. He refers to Roslonski (1933) who found that in east Europe precipitation is higher than evapotranspiration from August on, because of which the water level is kept high throughout most of the year.

Doherty and La Roi (1973) found in the Peace-Athabasca delta that flood-waters having entered a closed lagoon were retained by the levees at a new and higher level and fluctuated very little except upwards after heavy precipitation or rapid snow melt. However, "during the years following flood there is a gradual net drawdown in water level, since annual evapotranspiration exceeds precipitation and a gradual build-up of organic material" (Doherty & La Roi 1973 p. 209).

In the Laitaure delta the frequency of high flooding is two years out of three (see section 2.4) at which time the basins are filled up. According to Tamm (1959) (see also section 2.3) the precipitation surplus is about 400 mm per year and thus the closed basins have a fairly constant low water-level equalling the low water threshold.

8.1.2. Compaction of sediments and subsidence of land

Dahlskog (1966 p. 98) claimed that "old maps, topography, drainage network, soil conditions—all show that parts of the deltas along abandoned distributaries are slowly sinking (be-


cm
L105
250
200
POTAMOGETON ALPINUS - SPARGANIUM SP. VEG. OR
DREPANOCLADUS TRICHOPHYLLUS - CALLIERGON GIGANTEUM VEG. DEAD SEDGE CLUMPS
TUSSOCKY REEDSWAMP
SEDGE REED SWAMP ON SOD
MIXED SEDGE SWAMP ON SOD - FLOATING
ERIOPHORUM ANGUSTIFOLIUM SWAMP
DETERIORATED WILLOW VEG. DOMINATED BY SEDGES
DETERIORATED WILLOW VEG. MOSS-COVERED
WILLOW VEGETATION WHERE OPEN WATER COVER THE GROUND MOST OF THE YEAR
DEAD OR DYING BIRCH OR WILLOW VEGETATION WITH TERRESTRIAL AND TELMATIC SPECIES
f
REEDSWAMP
INTERJACENT SWAMP
SHOREWARD SWAMP
INTERJACENT WILLOW SUBZONE
LEVEE-WARD WILLOW SUBZONE
cm
L36
300
250
POTAMOGETON ALPINUS SPARGANIUM SP. VEGETATION
TUSSOCKY REEDSWAMP
SEDGE REED-SWAMP ON SOD
MIXED SEDGE SWAMP ON SOD
ERIOPHORUM ANGUSTIFOLIUM SWAMP
DETERIORATED WILLOW VEG. SEDGE OR MOSS DOMINATED
WILLOW VEG. WHERE OPEN WATER COVER THE GROUND MOST OF THE YEAR
TALL WILLOW VEGETATION TELMATIC SPECIES
BIRCH DOMINATED VEGETATION TYPES
e
REEDSWAMP
INTERJACENT SWAMP
SHOREWARD SWAMP
INTERJACENT WILLOW SUBZONE
LEVEE-WARD WILLOW SUBZONE
cm
L51
250
200
POTAMOGETON ALPINUS - SPARGANIUM SP. VEGETATION
CAREX ROSTRATA REED-SWAMP
SEDGE REED SWAMP ON SOD
MIXED SEDGE SWAMP ON SOD
SCATTERED DEAD OR DYING WILLOWS IN MIXED SEDGE SWAMP
DETERIORATED WILLOW VEG. DOMINATED BY SEDGES IN THE FIELD-LAYER
DETERIORATED WILLOW VEG. DOMINATED BY MOSSES
TALL WILLOW VEGETATION TELMATIC SPECIES
BIRCH DOMINATED VEGETATION TYPES
d
REEDSWAMP
INTERJACENT SWAMP
SWAMP-WILLOW SUBZONE
INTERJACENT WILLOW SUBZONE
LEVEE-WARD WILLOW SUBZONE
cm
L71
250
200
150
POTAMOGETON ALPINUS - SPARGANIUM SP. VEGETATION
SEDGE REEDSWAMP ON SOD
MIXED SEDGE SWAMP ON SOD
MIXED GRAMINID SWAMP
CLOSED WILLOW SHRUB VEGETATION INITIATED IN SWAMP VEGETATION OR SCATTERED WILLOW SHRUBS IN MIXED GRAMINID SWAMP
TALL WILLOW VEGETATION TELMATIC SPECIES
TALL WILLOW VEGETATION TELMATIC TERRESTRIAL SPECIES
TALL WILLOW VEGETATION TERRESTRIAL SPECIES
LOW WILLOW VEGETATION ABUNDANT BIRCHES
c
REEDSWAMP
INTERJACENT SWAMP
SHOREWARD SWAMP
SWAMP-WILLOW SUBZONE
INTERJACENT WILLOW SUBZONE
LEVEE-WARD WILLOW SUBZONE
cm
L69
200
150
100
ELEOCHARIS ACICULARIS - SUBULARIA AQUATICA VEGETATION
REEDSWAMP WITHOUT SOD
MIXED SEDGE SWAMP ON SOD
MIXED GRAMINID SWAMP
SCATTERED WILLOW SHRUBS IN MIXED GRAMINID SWAMP
TALL WILLOW VEGETATION TELMATIC TERRESTRIAL SPECIES
TALL WILLOW VEGETATION TERRESTRIAL SPECIES
LOW WILLOW PIONEER VEGETATION WITH SCATTERED BIRCHES
b
REEDSWAMP
INTERJACENT SWAMP
SHOREWARD SWAMP
SWAMP-WILLOW SUBZONE
INTERJACENT WILLOW SUBZONE
LEVEE-WARD WILLOW SUBZONE
cm
gauge1
200
150
100
ELEOCHARIS ACICULARIS - SUBULARIA AQUATICA VEGETATION
REEDSWAMP WITHOUT SOD
MIXED SEDGE SWAMP
MIXED GRAMINID SWAMP
MOSS-COVERED SWAMP
TALL WILLOW VEGETATION TELMATIC TERRESTRIAL SPECIES
TALL WILLOW VEGETATION TERRESTRIAL SPECIES
LOW WILLOW PIONEER VEGETATION
LOW WILLOW PIONEER VEGETATION WITH SCATTERED BIRCH SHRUBS
a
REEDSWAMP
INTERJACENT SWAMP
SHOREWARD SWAMP
INTERJACENT WILLOW SUBZONE
LEEVE-WARD WILLOW SUBZONE
10 20 30 40 number of days
DEVELOPMENT OF BIRCH DOMINATED VEGETATION TYPES NOT LIKELY
DEVELOPMENT OF BIRCH DOMINATED VEGETATION TYPES LIKELY
1
2
3
4
5
6

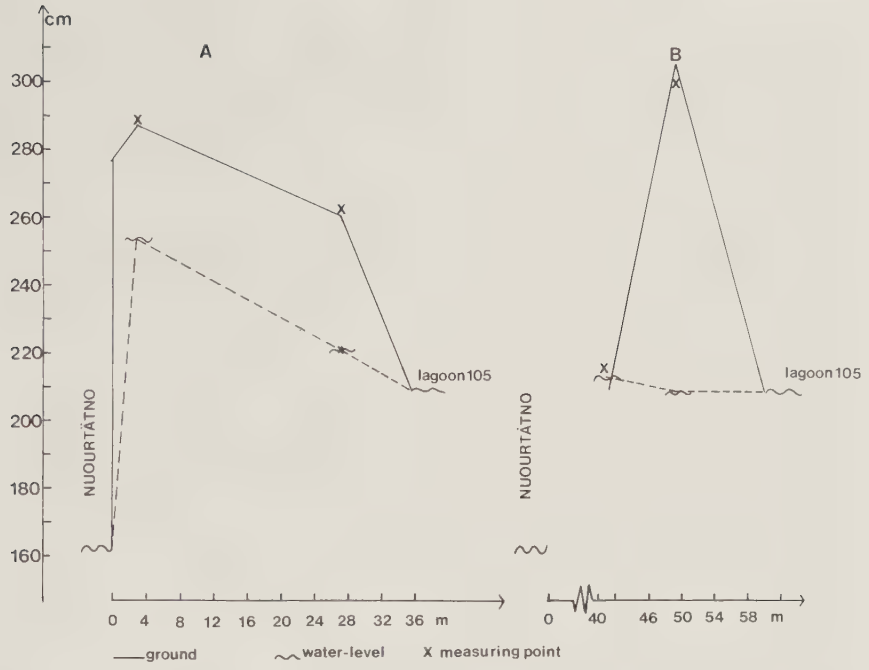


Fig. 85. The water-level in the ground at a few places between lagoon 105 and the distributary Nuourtätno east of the lagoon, 10 July 1972. The water-levels were measured in holes dug at intervals. There was about 100 metres between the two measuring lines A and B. The levee is comparatively broad at B. For position see Fig. 4.

A. The water-level in the birch-covered area 8 metres from the shore of lagoon 105 was 12 cm above lagoon level. The water-level in the ground 3 metres from the distributary was 44 cm above lagoon level and 91 cm above distributary level. The high water-level in the ground close to the distributary was probably caused by the very high water-level of the day before the measurements were made.

B. There was no difference in water-level in the ground 10 and 16 metres from the shore of lagoon 105. The hole at 50 metres was dug in an old dune, covered by birches, at 40 metres there was water above ground level. It has also been noticed in other areas that the water-level in dunes is comparatively low.

Fig. 84. An example of a possible development of the vegetation zonation between a levee crest of an active distributary and the open water of a lagoon, in a sequence from a young bay (a) to an old lagoon (e, f), having different water-regimes. The level and height of the used transects have been equalized, as well as the development of the vegetation. A few unpublished levelled transects have also been used. Vegetation zones distinguished are shown. The duration of water-levels in number of days during June 14–July 24 and August 31–9 September 1973, a total of 51 days, is shown for each transect. The water-level at freeze-up in the lagoons on 24 September 1973 is marked.

The top figure (f) shows the zonation and vegetation types from a levee along a distributary abandoned shortly after bifurcation. The levee is comparatively low partly due to the early abandonment but a slight compaction and lateral displacement of sediment might have lowered the levee to some degree. The levees along the distributary are flooded less frequently with height and the sedimentation does not reach so far into the basin as in the young stages. The main distribution of different grain sizes along the transects are shown. The deposition of silty sediment in the areas with sod is not indicated but deposits in the sods are found.

1. Initial bar, built-up by sediments transported as bed-load, the top-sediment in the sheltered lower part is usually silty; 2. Sandy loading usually deposited at high water when the levees are overflowed; 3. Silty loading, usually deposited from suspended load in calm water; 4. Sod; 5. Suspension of water, silt and organic material (floating sods); 6. Water-level duration.

cause of soil-creep, compaction and consolidation)" and was of the opinion that "such subsidence seems to be an inherent part of delta evolution and is not due to special conditions". Comparison was made with Russel's description from the Mississippi delta (Russel 1936). Dahlskog (1966 p. 100) remarked that: "If a delta is growing rapidly, owing to great sediment transport and small basin depth, then pioneer communities will occupy a large part of the land area, sinking communities will be extremely rare or absent, well-developed tall herb forests will be rare because of rapidly shifting channels and so on (the Laitaure and Tarraure deltas)." Evidently, his reference to the Laitaure delta was not quite correct in respect to sinking.

Russel (1936) showed that large areas in the Mississippi delta have been and are continuously being submerged. Is this chiefly the result of regional subsidence, local subsidence near accumulation of sedimentary load, local settling of objects on insecure foundations or sedimentary compaction? The writer (i.e. Russel) is inclined towards the opinion that all of these factors are operative. In favour of regional subsidence, he notes "the general drowned conditions of the entire northern Gulf coast" (Russel 1936 p. 176). He also states; "That sedimentary compaction takes place is an admitted fact." The sediment compaction discussed by Russel concerns old and deeply buried sediments in which compaction is a part of bedrock formation. Local settlings on insecure foundations is undoubtedly an important factor in some of the subsidence and levee flank depression seems most readily explained on this basis (Russel 1936). Although Russel gives many examples of local settling of objects on insecure foundations, he is not sure of its importance.

Coleman and Gagliano (1964) showed a cyclic deposition of different kinds of delta sediments. When accumulation of sediment ceases in an area the general subsidence takes over and the area is submerged.

Samojlov (1956) was of the opinion that the subsidence of the Mississippi delta was not a cause of compaction due to an overburden but to the fact that the Mississippi delta is situated at a geosynclinal. He also refers to the fact that only 2 % of the load of the river is deposited in the delta region. Russel's support of his theory of submergence due to compaction from the Rhone delta (Russel 1942) was denied by Samojlov (op. cit.) as he concluded that this delta is still situated at the 0-isobase.

Morgan (1970b p. 111) claims that "possibly the most important, but usually the least considered, factor that influences deltaic sedimentation is the structural behavior of the depositional sites with respect to sea level as a datum". He distinguishes three possible alternatives, either a structurally elevating area, a stable or rigid platform or a subsiding area. He also writes that when a distributary becomes abandoned and "the supply of clastics diminishes, the continuing process of subsidence through sediment compaction and water loss becomes dominant" (Morgan 1970b p. 114). He also calculates the weight of the sediments and states "that replacement of water by sediments in Bay Rondo (Mississippi delta) has loaded the underlying delta platform with some 2 billion tons" (clay-silt with an average unit of weight of 1.8 g/cm^3). He furthermore states that: "The effectiveness of such localized loading in causing compaction becomes readily apparent when the crevasse is abandoned and sedimentation ceases" (Morgan 1970b p. 115). Morgan (1970a) concludes after having compared the Mississippi delta, the Granges-Brahmaputra delta and the Mekong delta, that the main cause of the structural differences is the possibilities for the delta area to subside, and writes that "deltaic deposits cannot subside during progradation, either because of small size and insufficient mass or because it is underlain by a rigid basement" (Morgan 1970a p. 47).

Kanes (1970 p. 88) reports from the Colorado River delta that "In the period of years (1933–1956) since formation of the delta, the initial ragged bay margin was cut back and smoothed; embayed areas and lakes enlarged; beach ridges developed; and wash out pans were established. The first three of these changes apparently resulted from local subsidence due to gradual compaction of the underlying sediments. Although no direct evidence of this compaction was observed for the Colorado delta, an equivalent phenomenon is a characteristic feature of many large deltas".

Scruton (1960) explains the destructional phase: "when a river shifts its course for a shorter path to the sea delta building ceases locally, but compaction of the watery fore-set beds goes on, and ocean wave and current action continue unabated".

Scholl and Stuiver (1967) calculated the eustatic submergence of the Atlantic coast of America and found that the Gulf coast and the Mississippi delta have undergone submergence since the sea level reached a stable level about 3650 years ago.

Nelson (1970) reports that the Po River delta is sinking at an average rate of 7 to 8 cm per year and that maximum rate of subsidence is near the area where the most rapid sedimentation occurs. He describes this subsidence to be due to deltaic characteristics and an independent phenomenon.

Gould (1970), investigating the Mississippi River delta, states that there is a regional downwarp in this area and that the great load of the Mississippi is carried through the distributaries but deposited in the prodelta environment seaward of the sand accumulation. But during floods the entire delta plain becomes a site of deposition and it is in this way that the plain has kept pace with subsidence and maintained its near sea-level position. Following abandonment, each of the shoal-water deltas continued to subside, allowing marine waters to transgress its seaward margin.

Oomkens (1970) shows the sequence of different marine and fresh water delta sediments in the Rhone delta. The deposition of marine sediments seems to be mainly a result of a raised sea-water level.

From the Peace-Athabasca River delta, Bayrock and Root (1970 pp. 30–31) report that: "Silts and clay are deposited in an oozy state in aquaeous environments and undergo a considerable compaction upon the expulsion of intergranular water. Pure sands compact very little. Most of the compaction takes place very shortly after deposition and most of the delta regions of the world show compaction and subsidence. The Peace-Athabasca delta has areas which closely resemble areas that have subsided following sediment compaction: As there is no direct proof of compaction in this delta the areas are called drowned areas. These are present as a wide belt along the distal parts of the Peace-Athabasca delta west of

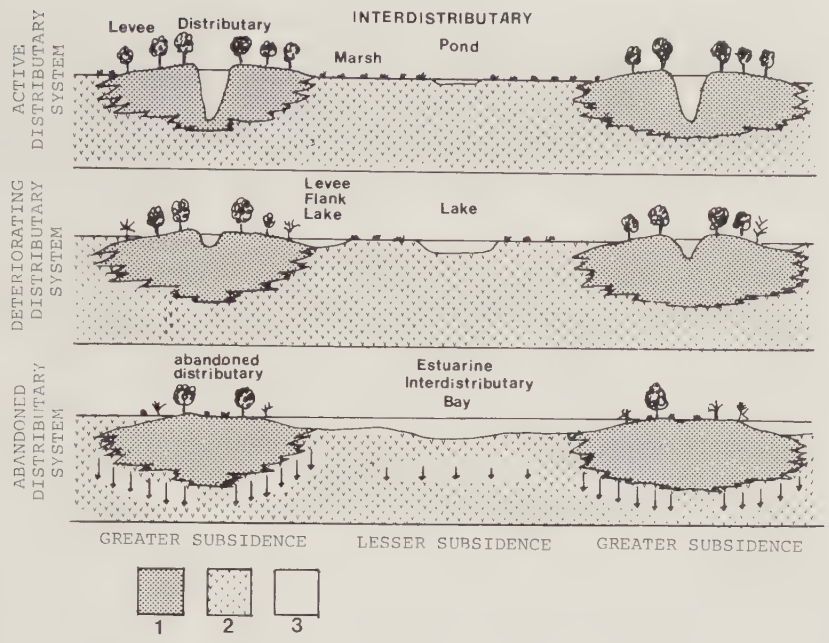


Fig. 86. Influence of sediment compaction in causing subsidence during distributary system abandonment (After Morgan 1967, from the Mississippi delta). In some areas this unequal subsidence might add to the rise in low water-level. 1. Sand and silts (specific gravity 1.7–1.9); 2. Organics, silts and clays (specific gravity 1.5–1.7); 3. Water.

Mamawi lake. The Birch River delta has correspondingly smaller drowned areas. Destruction of the Peace-Athabasca delta by wave action is considerable especially in the inactive portions."

Gill (1971 p. 223 in discussion) notes from the Mackenzie delta that: "In lakes which are connected to channels there is an infilling of sediments during flood stage and this allogenic process creates the most productive marshes of the Mackenzie delta" while "many of the lakes which are not directly connected to distributaries do not receive sediment thus undergo thermokarst activity. These lakes enlarge at the expense of surrounding vegetation, thus a retrograde situation develops where plant succession cannot take place." In a discussion with Gill (Gill 1971 p. 226) Schweger asked: "Don't you think that there might be a residual subsidence which could lead possibly to an embayment of marine water into the Mackenzie region if the annual increment of flood waters and sediments were not added ..." Gill (1971 p. 226) answered: "subsidence occurs very little in the Mackenzie delta because of permafrost. Once a substratum is frozen, subsidence is negligible. If mesoclimatic conditions would continue to cool and if the lakes froze to the bottom so that permafrost penetrated deeper, this would in fact minimize subsidence even further, thus subsidence should not occur."

McCloy (1970), working at the Blow River delta, a 51.8 km^2 large delta with a permafrost thickness of 30.5 m, also reports on enlargement of lakes by thawing and slumping. He has also investigated the construction and destruction of delta levees and the phenomenon of discordant levee height but reached a very contradictory result.

Gill (1972a p. 234) describes the hydrology of the meander scroll depressions of the Mackenzie River delta as "such depressions are significant in affecting the distribution of vegetation, especially by impounding water to greatly affect biota". He continues: "They are seldom inundated by spring floods, but nevertheless collect water annually, receiving sufficient runoff from locally melting snow and/or spring rains to become bankfull. Permafrost seals the bottom of these depressions, making drainage impossible, causing them to remain flooded for much of the summer. If the Mackenzie delta were not underlain by permafrost, ponding in these depressions would still most likely occur, since they are sealed by layers of fine clay deposited during floods at sufficient height to overtop the scrolls." Gill (1972a) also refers to a work by Kolb & Van Lopik (1958) who reports a clay sealing of the bottoms of meander scroll depressions in the Mississippi River delta: Gill (op. cit) regard this ponding in meander scroll depressions as probably being an universal geomorphic condition of floodplains. In the Laitaure delta almost all meander scroll depressions have a high water level throughout the year.

Morgan (1967) distinguishes between geosynclinal downwarping and "the effect of overloading with resulting compaction and water loss by underlying sediments". He considers subsidence through compaction during short periods such as the interval of stillstanding more important than subsidence due to geosynclinal downwarping. He also calculates the subsidence of the Mississippi delta to vary between about 0.05 feet and 0.13 feet per year and states that "such rapid subsidence rates are a product of the initial high water saturation of deltaic sediments. ... coarser massive bar and levee deposits compact underlying silts, silty clays, and fine-grained prodelta clays by elimination of interstitial water. Compaction initially is quite rapid but becomes progressively slower as moisture content is depleted. In addition, lateral displacement by plastic flow in underlying fine-grained sediments has been shown to be a significant process in a distributary mouth which results locally in abnormally high sub-

sidence rates" (Morgan 1967 p. 116). He also states that "distributary levees are more massive than adjacent marshes and consequently subside more rapidly. With subsidence, levees often drag down the adjacent marsh to form elongated open ponds paralleling the outer levee margins. Such features have been named 'levee flank depressions' by Russel (1936)." (Morgan 1967 p. 117.) See Fig. 86 from Morgan 1967.

This kind of subsidence may well work at the Laitaure delta but is probably not of major importance. The sediment thickness is between 4 and perhaps 20 m, the sediment of the foreset bed is prevailingly sandy and the retrogressive succession does not just follow abandoned distributaries. As compaction is strongest initially it would decrease with time. The flattened kind of levee pair shown in Fig. 86 can also be found at the Laitaure delta but need not have the same origin as described by Morgan (1967). In the Laitaure delta low and flat levees are found along angled abandoned distributaries, although young and lately abandoned, i.e. the levees west of lagoons 70, 61 and 60 (see Fig. 4). The levee pair west of lagoon 80 (see Figs. 4 and 21) is an exception, being highly influenced by windblown sediments.

Levee flank depressions are found in all closed lagoons and could be a consequence of subsidence and soil-creep of the levees but also depend on the fact that the sod of the swamp has grown thicker as the water-level has been raised, thus giving the impression of a depression close to the levee, see Fig. 31.

Investigations on compaction and compressibilities of sediments have mainly been performed with either pure sand or clay with reference to sandstones and shales. Investigations of mixed natural sediments have started quite recently using X-ray technique. The consolidation of and possible compaction of different sediments is due to the particle size of the sediments, the initial porosity, the depositing rate, the overburden and the thickness of the initial sediments (Pettijohn 1975).

8.1.3. Conclusions

There are several processes which could be responsible for the different structures in open and closed lagoons. Such possible causes as (1) unequal land uplift and (2) gradual raising of the delta level when its front is expanding lakeward at constant slope should be ruled out because these processes are too small in magnitude and too slow. They might however accentuate the drowning alongside closed lagoons. Moreover, they would produce a more uniform result than the actual diversification of the lagoon habitat. The same could be said about (3) compaction of the delta sediments, which could explain the increasing open water surface and the drowned willows, for example, but not the unequalness of these phenomenon being confined to lagoons having a low water threshold. (4) In closed lagoons mineral sedimentation is strongly reduced since the water is usually not turbid in contrast to the high silt deposition in open lagoons. But this explains only the rapidity of the progressive succession in some open lagoons and not the retrogressive development just mentioned. It seems likely therefore, that the latter are results of the increase in low water-level in the closed lagoons mentioned above. The higher low waters could act both as (5) higher averages during the vegetation period and as (6) higher and less long-lasting minimum levels, perhaps especially important with regard to conditions at freeze-up and before thawing of the thick winter ice when the lagoons are flooded by local melt water and eventually by distributary water.

8.2. Initial breadth and stability of vegetation zones in bays and open lagoons

The breadth of the different zones in a bay or an open lagoon is probably a consequence of differences in the ground level caused by the differentiated spreading of the water and sediments at bankfull stage (see Fig. 87),

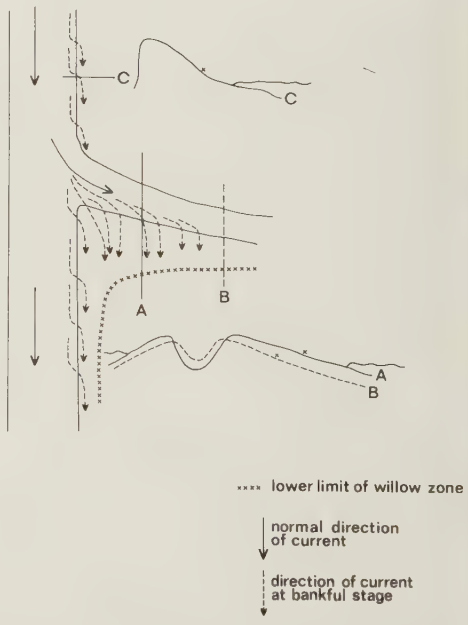


Fig. 87. Direction of current at initial bankful stage. The current follows the general direction of the streaming water when the levee crests have been overtopped. The setting of the lower limit of the willow zone is largely decided by the extent to which the coarse sediment load reaches into the interlevee basin. A, B and C show the cross-section of the levees and distributaries. The amount of water in an angled distributary gets less the greater the distance away from the main distributary, with lower levees and shallower distributary as a consequence.

in relation to the water-level variation in the basin. The willow and swamp zones are broader downstream of a distributary which passes at an angle to the main direction of the flow or downstream of a concave bend. Along a straight distributary or upstream of an angled one the zones are, in contrast comparatively narrow. "Water which leaves the channel and flows over the flood plain tends to move directly downvalley rather than to follow the longer distance along the more sinuous path of the channel" (Wohlman & Leopold 1957 p. 101). Due to the straightening of the distributaries the connections between a concave bend and the breadth of the vegetation zones is not always evident. These broader zones are indicated in Fig. 4. In young basins with immature levees the frequency of bankful flow is higher than in areas with higher levees.

The coarsest sediment is deposited close to the distributary upon or near the levee crest, and the particle size and the quantity of the sediment deposited both diminish towards the lagoon (see section 2.1.3). The particle size of the sediment downstream of an angled distributary or a bifurcation is coarse since the current is too swift at overbank flow for the finer particles to settle. "The downvalley slope may be considerably greater than that of the channel (distributary), and this higher gradient tends to keep the velocity high and reduces the probability of deposition" (Wohlman & Leopold 1957 p. 103). Although this is stated about flood plains it can, in places, also apply to a delta.

Judging from the development of the vegetation in lagoon 69 and in lagoons 61 and 62 (section 5.2.1) it could be said that the distribution of the different vegetation zones is maintained fairly stable in bays and open lagoons. This might, however, be an illusion because a short-time cyclic development of the zones may take place when the zones expand during a couple of years and then become depressed during one or two extreme years (cf. Rørslett 1977). Dirschl (1971) describes the vegetational changes in the Peace-Athabasca delta in response to a reduced high-water discharge with no spring floods. He notes that especially the large lagoons with distributary connection get a smaller water area, and former sedge-dominated areas become invaded by *Calamagrostis* spp. and willows. He also concludes that the vegetation zones before the drawdown were developed as a response to the fluctuating water regime and therefore adapted to it.

The different vegetational zones in the open lagoons mentioned in this paper had the same distribution for 80 years in spite of the fact that the vegetation around at least lagoon 69 has been reached by turbid distributary water, although possibly only receiving suspended fine sediments during this time. Compaction of the recently deposited sediments could also contribute to the seemingly permanent swamp limit as consolidation of the sediments makes the amount of deposited sediments negligible in raising the ground level in relation to the water-level variation. Only at the mouth of channels of distributaries carrying turbid water has any expansion of the vegetation occurred.

8.2.1. The swamp zone

The deposition of sediments in the lagoon (69) has probably not been large and it has not raised the ground level enough to permit expanded colonisation of swamp species. Besides consolidation of sediments the permanently fluctuating water-level will cause the upper sedimentation limit to vary and sediments might become eroded on the waterward side of the reedswamp. Tutin (1941) regards the vegetation under water as a "climax" since wave action along the shores of a lake hardly ever permits expansion of reed species except in sheltered bays. *Carex aquatilis* and *Equisetum fluviatile* can probably only colonize downward to limited depths where the inundation at high waters does not last very long, but on the other hand, the exposure at low waters is also not too long. A too long-lasting high water in summertime may exhaust the individuals by encouraging growth (Millar 1973) since these species probably photosynthetize well only above the water table. By wave erosion at low water the roots may become exposed and specimens may even be eroded away. Jeremy & Tutin (1968) noted that the stems of *Carex aquatilis*, contrary to many other species, are brittle and snap on bending even in the fresh state, which is why wave action also might be an agent in restricting the distribution of the species. The very distinct lower limit for the sedges and horse-tail could also be caused by ice-pressure or erosion, although in autumn the water-level is generally below this zone. Freeze-up of the sediments in springtime thus seems a more probable cause (cf. also Lohammar 1948).

In lagoon 69 I have measured the depth at the limit of *Carex aquatilis* along 200 metres of the shore and it does not grow below a certain level. Here the horisontally undulating lower boundary of the swamp zone seems solely to depend on the level of the ground, except in exposed areas where wave erosion presses the zone boundary landwards.

8.2.2. The willow zone

The willow zone around lagoons 69, 61 and 62 had the same breadth from 1904 to 1974, and all irregularities along the swamp-willow border in 1904 can be detected in 1974. In area A2 (see Figs. 39, 40 and 41) the willow

zone might have expanded, forming a swamp-willow subzone. The willow zone around these lagoons seems to be very stable. Judging from the time needed to develop the large interlevee basin of lagoon 69, the willow vegetation could be at least 400 years old in the western part of the basin, i.e. the interjacent subzone and the subzone close to the levee of the willow zone in area A2 (Figs. 39, 40 and 41).

Willow seedlings thus seem to have a definite limit for growing, possibly decided by the frequency and duration of flooding. Kramer (1951) found experimentally that flooding of the soil caused injuries to plants. For example, privet *(Ligustrum)* died after 12 days of flooding. The injuries and death of shoots of flooded plants is thought to be caused by a complex of factors, including, reduced photosynthesis and gas exchange, and possibly also water absorption. Perhaps most injurious to plants not adequately equipped with airspaces in the roots (contrary to true mire plants) may be anaerobic conditions created in the surroundings of the roots. Under reducing conditions roots may also be dying from the formation of toxic products. Flooding may be more easily resisted on coarse permeable soils than on delta sediments or peat. Wassén (1966) and Dahlskog (1975) have given data on the duration of flooding in zoned shore vegetation. However, whereas young willow plants are frequently found beneath the proper willow belt on freshwater shores (see Dahlskog 1975), old specimens are generally restricted to areas with fairly short duration of the inundation in most years. On the other hand, under favourable conditions willows are able to spread their roots into open water. Hosner (1958) found that current year's seedlings of Black willow (*Salix nigra* Marsh.) could survive 32 days of complete inundation while the other 6 species he mentioned all died.

8.2.3. The birch zone

In the Laitaure delta birches are only found, no matter the age of the area, on the levee crests along active or abandoned distributaries, on point bars and in areas subjected to deposition of windblown sediments. Birches have also developed in the subzone of the willow zone close to the levee crest. This restriction of the birch vegetation is probably caused by the size of the particles of the minerogenic sediments in the ground, the coarsest sediment being deposited close to the distributary. The areas covered by birch vegetation were quickly raised well above mean water-level mostly by fairly coarse sedimentation. Dahlskog (1966 p. 99) points out from the Kvikkjokk delta that "if sedimentation has elevated the locality to a sufficiently high niveau (which depends on exposure), *Betula* forest develops directly from the late pioneer communities: if the locality has not reached as high a niveau, *Salix phylicifolia* brush develops". Gill (1972b) shows that *Populus balsamifera* can only develop on the point bar environment "where fluvial and aeolian processes are sufficiently intense to create a significantly drier and warmer soil. Sediment sorting thus becomes one of the dominant ecological factors in the successional ecology of the *Populus* ecosystem" (Gill 1972b p. 1392). Lindsey et al. (1961) pointed out differences in the lowest level for many species in two rivers with dominant sediment coarseness of different size and found lower levels the coarser the material.

In the Laitaure delta it seems that birches can only develop in areas reached by coarse, mainly sandy sediments, or perhaps more accurately expressed, in areas with small depositions of silt. The coarse sediments create drier conditions than anywhere else in this delta so dominated by wetlands.

In areas A1 and A2 (Figs. 39, 40 and 41), for example, birches have only developed close to the former distributary A, and in spite of the possible age of the willow zone, 400 years, birches are nowhere found in the willow zone. The difference in level, however, between the larger part of the birch-covered area and the willow-covered area is only around 10 cm and locally none. Any establishment in the mostly very dense willow zone must be difficult.

8.3. Expansion of the vegetation zones

The zones seem to be quite stable (see section 8.2), but when the levees have matured and become covered by willows or birches the zones might under certain circumstances expand into each other.

8.3.1. The swamp zone

The swamp vegetation in lagoon 71 (section 5.2.2) seems to have expanded between 1904 and 1974. The probable cause is that the former open connection with the distributary was replaced by a long but narrow channel during this time, diminishing the water-level amplitude (cf. also Clements 1916 p. 53). In lagoon 71 the low-water threshold is not high enough and has not worked long enough to cause retrogressive development in any larger areas. The northern border, area C5 (see Figs. 48 and 49), is steeply inclined but in area C1 the field layer is markedly influenced by a raised water-level, as is also the swamp vegetation in area D2.

In a newly formed bay I have recorded the swamp zone expanding into the *Eleocharis acicularis – Subularia aquatica* vegetation. In an open bay with immature levees the vegetation zones can be said to be on their way to adjust to the actual water-level variation.

8.3.2. The willow zone

In lagoon 71 willow shrubs have established themselves in the swamp zone of 1904. It is, however, not possible to say whether there has been an entirely new colonisation or if small willow shrubs or seedlings were present in the swamp already in 1904. A broadening of the willow zone by the development of a swamp willow subzone can also be seen, for example, in lagoons 69 and 70.

The migration of the distributaries can also cause an expansion of the willow zone into the swamp zone. This has happened for example, along the western border of the basin of lagoon 4 and along the south-western border of the basin of lagoon 60 (see Fig. 67), where erosion has greatly lowered the levee crest with heavy overbank deposition as a consequence. Up to 30 cm of sand has been found in the swamp zone of lagoon 69, and willow shrubs are rapidly colonizing this area.

8.3.3. The birch zone

Birches have not established themselves in any areas that were covered by closed scrub in 1922, except in those sites mentioned in section 8.2.3 but birches could also establish themselves following heavy overbank deposition. Also all photographic evidence points to this fact.

8.4. Disintegration and die-off of swamp vegetation

The swamp vegetation has disintegrated most markedly and over the largest area in lagoon 36 but in all closed lagoons there are areas where the swamp vegetation has been replaced by open water with or without living clumps of *Carex aquatilis* or with dead clumps at the bottom of the lagoons.

The water-level variation in a closed lagoon is within a smaller range and is also slower during the vegetation period than in an open lagoon, but perhaps the most striking difference is the high water-level at freeze-up, when open lagoons have low-water conditions, like the distributaries. In lagoon 36 the swamp zone disintegrated at the same time as the channel became inefficient or at least, developed a rather high low-water threshold. This gives raised low water-level as the most probable cause for the die-off of swamp vegetation.

Carex aquatilis and *C. rostrata* under more or less permanently raised water-levels have not been studied experimentally. Sjörs & Nilsson (1976 pp. 21, 29) report survival and even greater size in *C. rostrata* growing near the damming limit in reservoirs. These reservoirs are filled in summer and emptied in winter. There are also reports on the behaviour of other species exposed to raised water-levels. Millar (1973), working in Canada with raised water-levels in shallow wetlands *(Carex atherodes, Scolochloa festucacea* and *Eleocharis palustris)* which usually were dry after midsummer, shows that the presence of standing water during a single winter was enough to induce at least a partial die-off. The probable cause according to Millar was failure to grow in springtime. He also states that "The water depth at the start of the growing season could be a factor inducing die-offs but only 9 % of all species die-offs occurred with May water depth of 76.2 cm or less". This depth being greater than normal in May might induce partial die-off but Millar's results suggest that over-winter flooding is required to produce a total die-off of shallow marsh species. Millar (1973) also points out a few possible causes of die-off: (1) extra energy to grow the increased distance to the surface which could, among other things, weaken the individuals, (2) growth of new shoots is inhibited by the increased pressure from the added water depth (see also Laing 1941), (3) intolerance of plant species to anaerobic conditions during winter.

The ancient method (Frödin 1952) in parts of northern Fennoscandia to improve the production of sedge hay in wetlands was however to raise the water-level during winter. This seems to have hampered willows from colonizing the wet sedge fields used for haymaking, but not to have weakened the sedges.

McDonald (1955) found that drowning by too high water was the most logical explanation for die-offs of large areas of marsh vegetation (mainly *Typha, Scirpus* and *Phragmites*) in Lake Eire and Lake Huron. The water-level in these lakes had gradually been raised for three years, killing off trees and shrubs but the die-off of marsh vegetation took place after an extremely high winter water-level (16 cm or 7 inches higher than any previous winter for 16 years). "This rise was sufficient to submerge dormant shoots of cat-tail and other emergent vegetation throughout the winter over much of the marsh" (McDonald 1955 p. 27). McDonald found that it was after two winters with exceptional high water-levels separated by a number of years that marsh vegetation died-off. As the probable physiological cause for this McDonald writes (p. 27): "Normally

dormant shoots have access to air throughout at least part of the winter, a factor which Laing (1941) regards as very important for survival." Laing (1941) found that rhizomes could endure anaerobic conditions for a short period and McDonald concludes (p. 27) "but apparently not for the entire winter". However, any shoots reaching the air in winter are both frozen and snow-covered. Moreover, the rhizomes of these plants endure anaerobic soil conditions throughout the year, but deficiency in oxygen may arise inside the root and rhizome aerenchyme if there is no pathway for diffusion leading from the atmosphere.

Harris and Marshall (1963) found that *Typha angustifolia* and *Carex* spp. showed reduced abundance and vitality if the water depth was over 30 cm in the third year of reflooding, and died out completely when the high water-levels were maintained also a fourth year. The stands they investigated were areas colonized during 4 years of drawdown of the water-level, and it could be assumed that no sod had been developed.

Brink (1954) noted that the above-ground parts of nearly all sedges (e.g. *Carex rostrata*) died from flooding but soon after the recession of the flood new growth came from rhizomes. He noted that cold swift water did little but delay the growth of most species but slow-moving or stagnant, warm water, on the other hand, caused the death of nearly all aerial vegetation after a day or two under flood. He regarded the amount of dissolved gases to be very important for survival following flood.

As outlined in section 4.4.1, there are mainly 4 kinds of reedswamp vegetation to be found in the Laitaure delta: reedswamp with *Carex aquatilis* rooted in the bottom sediments, *Carex aquatilis* on a sod, floating or not, *Carex rostrata* reedswamp, and tussocky reedswamp. The *Carex rostrata* specimens found as reedswamp in deep water (~1 m) are very unlike normal *Carex rostrata*, being about 1.5 m high and with empty utricles, thus probably a hybrid. Harris & Marshall (1963) found a hybrid between *Typha latifolia* and *T. angustifolia* which survived in much deeper water than any of the parent species. When the reedswamp consists of *Carex aquatilis* rooted in the bottom it may well be possible that the specimens die, from one or the other of the causes outlined earlier, as a consequence of a raised water-level. Clumps and clones may perhaps survive and form tussocks. In the Laitaure delta *Carex aquatilis* does not endure water depth of more than around 60 cm maintained for any longer period of time (about one or two weeks). Very likely the species can survive much longer and higher inundations elsewhere in north Sweden. An acceptable explanation of the death of the species mentioned in the Laitaure delta from too high water levels, is that they are adapted genetically to be able to withstand the high-water amplitude in the open lagoons with very low water levels in winter (conditions that are normal in the boreal zone), and thus are no longer able to tolerate high-water levels throughout the year. The latter conditions are exceptional in this climate.

In Arctic North America both *Carex aquatilis* Wahlenb. and *Carex stans* Drej. (*Carex aquatilis* ssp. *stans* (Drej.) Hult., Hylander 1966) can be found. It is interesting to note that on Devon Island, *Carex stans* is very common and evidently grows as *Carex aquatilis* in the Laitaure delta, viz. forming the reeds in small pools and along streams (Muc & Bliss 1977). However, at Barrow Alaska, *Carex aquatilis* is found but rarely in the wettest habitats, but dominates the moist meadows which are dried out at least during parts of the year (Webber 1979).

McDonald (1955 p. 29) points out that "there is a possibility that surviving stands and single stems survived by means of an ability to withstand oxygen deficiency in some way, an ability which was again demonstrated in 1951–1952" (the second period of high water in McDonald's investigations). "This ability apparently developed independently in many different shoots, and was then selected by environmental pressure." Whether a similar selection is the cause for survival of *Carex aquatilis* clumps could be doubted since probably all rhizomes have aerenchyme and thus are able to resist anaerobic rhizosphere conditions. Moreover, the clumps disappear as time goes on.

McManmon & Crawford (1970) as well as Hutchinson (1975) came to the conclusion that when anaerobic metabolism is induced by a rise in water-level reducing the rate at which oxygen can diffuse to the roots, two different types of metabolic path may result, one in intolerant or more truly terrestrial species, leading to the ultimately toxic accumulation of ethanol, and the other in tolerant or facultatively aquatic species, leading to the accumulation of the far less toxic malate.

Carex aquatilis is evidently tolerant to flooding but the consequences of prolonged flooding have not yet been investigated. The behaviour of roots and rhizomes of *Carex aquatilis* at Barrow, Alaska, has recently been studied by Shaver & Billings (1975), Billings et al. 1976 and 1977, among others, and the photosynthetic competence by Tieszen (1974). However it is difficult to apply their results to the ecology of *Carex aquatilis* in the Laitaure delta since at Barrow there is no water above ground level.

Birger (1908) found free-floating rhizomes of *Equisetum fluviatile, Hippuris vulgaris, Phragmites communis* and *Nuphar luteum* in a 30–100 cm deep pool. The explanation according to Birger was that the

plants had been lifted up by the icebound parts of the plants at the clearing of the ice. Lohammar (1938) noticed that species with widely distributed rhizomes were not found on silt-dominated bottoms, which he explained by the fact that they were lifted by the frost. Reiersen (1942) explains the low frequency of *Equisetum fluviatile* to be an effect of the low water-level during the winter, making it impossible for it to withstand the frost.

The reedswamp and the interjacent swamp develop, as pointed out earlier, a sod of varying thickness which sometimes floats and locally is fastened to the bottom (see section 4.4). Kulczyński (1949) distinguished between heavy and light peat, heavy peat being slimy to a high degree and characterized by a high bulk density (specific gravity by Tomaszewski 1943 in Kulczyński 1949) under waterlogged conditions. Kulczyński (1949) pointed out the differences in behaviour of these kinds of peat. Heavy peat sinks when flooded and mires (fluvial mires) with heavy peat are the only kind of peatland which can develop on flat inundation terraces. Mires with light-weighing peat (containing rhizomes with aerenchyme and a strongly developed moss layer) float during the spring floods and would be carried off by the river current. The shoreward and the interjacent swamp subzones in the Laitaure delta are heavy both in closed and open lagoons and sink when flooded, but the reedswamp very often floats both in partly closed and in closed lagoons. The very fast disintegration of the reedswamp in lagoon 50 (section 7.2) could have been caused by the high flood in 1973 when the light-weighing sod could have been dragged away. *Carex aquatilis* clumps could then have been left as remnants of the former reedswamp vegetation. The swamp zone which disappeared developed between 1904 and 1954 and probably received only small amounts of minerogenic loading, thus having been light and possible to carry away.

Slow disintegration of swamp vegetation growing on a sod could also be due to the high water-level in the sense that species fail to grow due to the year-round flooding or to a high water-level at the start of the growing season (compare reedswamp without sod). Failure of the sedges to grow was seen in 1973 in lagoon 1 (Tjappisjaurats) as a consequence of a very thick snow cover which melted late and left a sparsely vegetation-covered area with open water in places where in 1972 there was a healthy sedge swamp on a thick sod. A high water-level at freeze-up such as is developed in closed lagoons, might also be an agent in the disintegration of the swamp vegetation. Doherty & La Roi (1973) report that severe ice-scouring occurred in a closed basin which at flooding got a high and stable water-level. Removal of entire plant communities and their accumulated organic substrates and subsequent enlargement of the aquatic habitat have been recorded. Such ice action in the Peace-Athabasca delta was usually accompanied by flooding and deposition of inorganic sediments. Wesenberg-Lund (1917) noted that the ice at break-up could loosen 1 m^2 large rhizome clumps.

In the open lagoons of the Laitaure delta there is usually no water in the swamp zone at freeze-up but in the closed lagoons 51, 36 and 105, for example, the sod is completely submerged at freeze-up. Depending on the conditions at freeze-up there are possibilities of frost action, for example, as ruptures in the frozen sod, which then may become eroded or broken up and initiate swamp disintegration. A floating sod, especially if cracked, might also well be dragged away by high water in spring-time. Even a sod which normally does not float may be lifted if still frozen when the water rises. A strong flood before ice thawing in the lagoons may thus cause removal of parts of the swamp vegetation.

8.5. Disintegration and die-off of willow vegetation

This problem includes retrograde displacement of the willow zone and the influence of a raised water-level on the shrubs.

Adjacent to all closed lagoons, both the ones presented in chapters 5 and 7 (viz. 51, 36, 60, 105, 84, 50, 34 and 35) and others not presented here, there are areas where willow shrubs have died or are dying. At open lagoons or bays, irrespective of their age, there are never any dying willow shrubs in the zonation from an active distributary. The breadth of the willow zone, as compared with that of the swamp zone, is also markedly narrower at closed lagoons than at open ones. The breadth of the willow zone reflects the water-level variation in the lagoon.

However, the distribution of the willow zone is frequently found to be larger than expected from the ecological conditions due to a delay in the retrogression of the zone, since the willows linger on even after conditions have become difficult, and some time is needed for the willows to die-off entirely and decompose. Everywhere it is in the lowest lying areas of the willow zone, viz. areas situated farthest away from an active distributary, where the willow shrubs begin to die. In the swamp-willow subzone the shrubs often disappear totally, while in areas with a closed shrub layer (where the ground has been slightly raised by the

roots and stems of the willows and by litter accumulation) remnants of the shrubs are visible for a long time, perhaps a century. Moreover, the water-level has to be raised much more to influence the higher situated parts of the willow zone. Evidently the willow near open lagoons with fluctuating water-level can endure submergence of their roots for a period of time that is not too prolonged. Several authors (Yeager 1949; Doherty & La Roi 1973) have noticed that willows show a marked ability to produce adventitious roots when flooded to an unusual level. Kramer (1951) suggests that there is a positive correlation between amounts of adventitious roots and the extent of injury or death of the original root system in *Salix*. In the Laitaure delta, adventitious roots have not been noticed on the willow shrubs near any open lagoon but are frequently found adjacent to closed lagoons (lagoons with a low water threshold) with a raised low water-level.

In the Laitaure delta a water-level of 30–40 cm above the soil surface in summertime in the willow zone lowers the vitality of the shrubs, and even with 2–3 cm of open water in the willow zone adventitious roots frequently develop. Harris & Marshall (1963) showed that well-established *Salix* was eliminated after 3–4 years of continuous inundation to 60 cm depth or more. Sjörs & Nilsson (1976 p. 28) found occasional willows surviving damming in reservoirs. Probably the important factor is not water depth but duration, especially duration of anaerobic conditions in the subsoil rhizosphere.

8.6. The time aspect of die-off of swamp and willow vegetation

There is some evidence in the photo material regarding the time needed for the dying-off of willow vegetation and the disintegration of swamp vegetation. These processes do not have to be continuous but may also result from drowning by 'catastrophic' or prolonged high waters, ice action or channel closing.

Development from 1904 to 1974: As mentioned earlier there were only 4 lagoons with easily distinguished tussocky reedswamp vegetation both in 1904 and in 1922. In 1974 the reedswamp vegetation in a large number of lagoons showed retrogressive development. Whether this accounts for the dying of willow shrubs as well cannot be stated, since the vitality of shrubs is poorly distinguishable from photos. The increase in number of lagoons showing disintegration of swamp vegetation in 1974 as compared with 1922 could have many explanations. The water discharge has not been significantly raised during the later part of the period. Instead, a slightly lower discharge has been recorded (see section 2.4.2). Thus a generally higher water-level could not be the major cause of the increase in number of lagoons showing retrogressive development. A lower water discharge, especially in July, might even have caused channels to close, as not being kept open by inflowing water. Vegetation might have been given the possibility to stabilize bars, etc.

The cessation of harvesting the swamp vegetation (see section 2.5) could also be a cause of the large number of lagoons with a tussocky reedswamp in 1974. Dredging is known to have been performed in one channel, but could also have been made in other channels draining large areas of valuable forage. The small basin of the lagoons 34 and 35 (see section 7.3), which on the map of 1884 (Fig. 9) are classified as 'mountain spruce', could have been considered too small to dredge. In lagoon 13 the areas with a tussocky reedswamp were small compared to the large area where harvesting was possible, as also applies to lagoon 55.

In the area of the Laitaure delta any influence of subsidence of the earth crust is very unlikely. Still, Lundqvist & Lagerbäck (1976 p. 50) were of the opinion that "although we have no record, as yet, of movement after late-glacial time, the possibility of present activity within the fault zone should be investigated". This fault ends some 40 km north of the Laitaure delta. This kind of subsidence would not cause but possibly only accentuate the retrogression in closed lagoons to an insignificant extent. By the slow aggradation process the bottoms of the distributaries are elevated to some extent causing a very slow gradual increase in the water-levels, but this can effect the vegetation only on a very different time scale.

In a few of the very old and large lagoons with distributary connection a few short levees of abandoned distributaries also show retrogressive development. This is perhaps a result of the development of a low low-water threshold in combination with compaction, soil-creep and wave erosion of the sediments building the levees.

In lagoon 84 (section 7.1) it is evident that from the closure of the lagoon some time around 1950 the willow zone has retreated about 30 metres by the dying-off of willow shrubs. The actual water-level in the willow zone and the number of years necessary to kill the shrubs cannot be stated from the investigations performed, but in lagoon 84 the willows have died in about 20 years. This fast die-off seems to exclude compaction of the sediments as an agent for reducing the difference in level between the ground and the low-water table. The levees around the basin are still low and immature, and thus the basin is flooded frequently.

Dahlskog (1972) points out that there is no true evidence of compaction in the Kvikkjokk delta but regards his results as possibly indicating that compaction may have measurable effects after periods of only 5–10 years, although only in localities where fine silt or finer material is deposited. Yeager (1949) studied the die-off of trees and shrubs in an artificially dammed area between two rivers. He found that 8 years of permanent flooding to a depth sufficient to cover the root collar, i.e. less than 20 inches (50 cm), were fatal. Black-willow *(Salix nigra)*was one of the species which survived best; only 43.5 per cent died in 6 years.

8.7. Classification of the delta lagoons

The purpose of classifying the different delta lagoons is to show the regularities in the development and the structure of the vegetation appearing in lagoons with the same geomorphological and hydrological history. The known development in the lagoons recorded on photographs since 1899 is the chief basis of this classification.

The development of an interlevee basin from an open bay to one or several lagoons, that in due course become closed, is continuous, although some phases are very slow and some may be fast. The development of a low-water threshold can induce a widespread retrogressive development although usually localized. A number of small lagoons are developed from depressions or wide parts in the original but cut-off channel, whereas the larger lagoons are remnants of the central bodies of water. They mostly decrease slightly during the early phases of progressive development but may be locally enlarged in the late phase of complete closure and retrogressive succession. The developmental lagoon classification arrived at is characterized in Table 6. The development of the drainage system of the delta lagoons is also shown in Fig. 4, where the indices of the lagoon numbers represent the drainage system of the lagoon in the beginning of this century compared with the drainage system in the 1970's.

8.8. The hydrarch successions in the Laitaure delta

Fuller & La Roi (1971) characterize the delta landscape system as being the predictable result of two opposing forces: "1. The tendency for aquatic ecosystems to be replaced firstly by wetland ecosystems and eventually by terrestrial ecosystems, through two complementary hydrarch successional processes—autogenic, in which species interact with each other and progressively 'build' a terrestrial habitat with undecomposed organic material—and allogenic, in which evaporative and drainage drawdowns of water levels accelerate the rate of replacement of wetter by drier ecocystems. 2. The tendency for spring floods to periodically (i.e. not every year) disturb, neutralize or modify the effects of hydrarch succession by raising the water level and causing either (a) partial or complete reversion to wetter ecosystems through elimination of some organisms and the creation of favourable environments for others, or (b) maintenance of ecosystems that would otherwise be succeeded by ones with drier water regimes, or ones with lower productivity or both." In addition to the above statement by Fuller & La Roi, I have also discussed the effect of raised low water-levels in disturbing the hydrarch succession. It may be added that not all autogenic successions in wetlands are hydrarch, and not all allogenic influences in a delta lead to drier ecosystems. Generally, delta processes tend to lead to increasing complexity of diversified patterns. Fig. 88 shows schematically the successional pathways thought to be the main ones, although not all parts of the delta necessarily go through these stages.

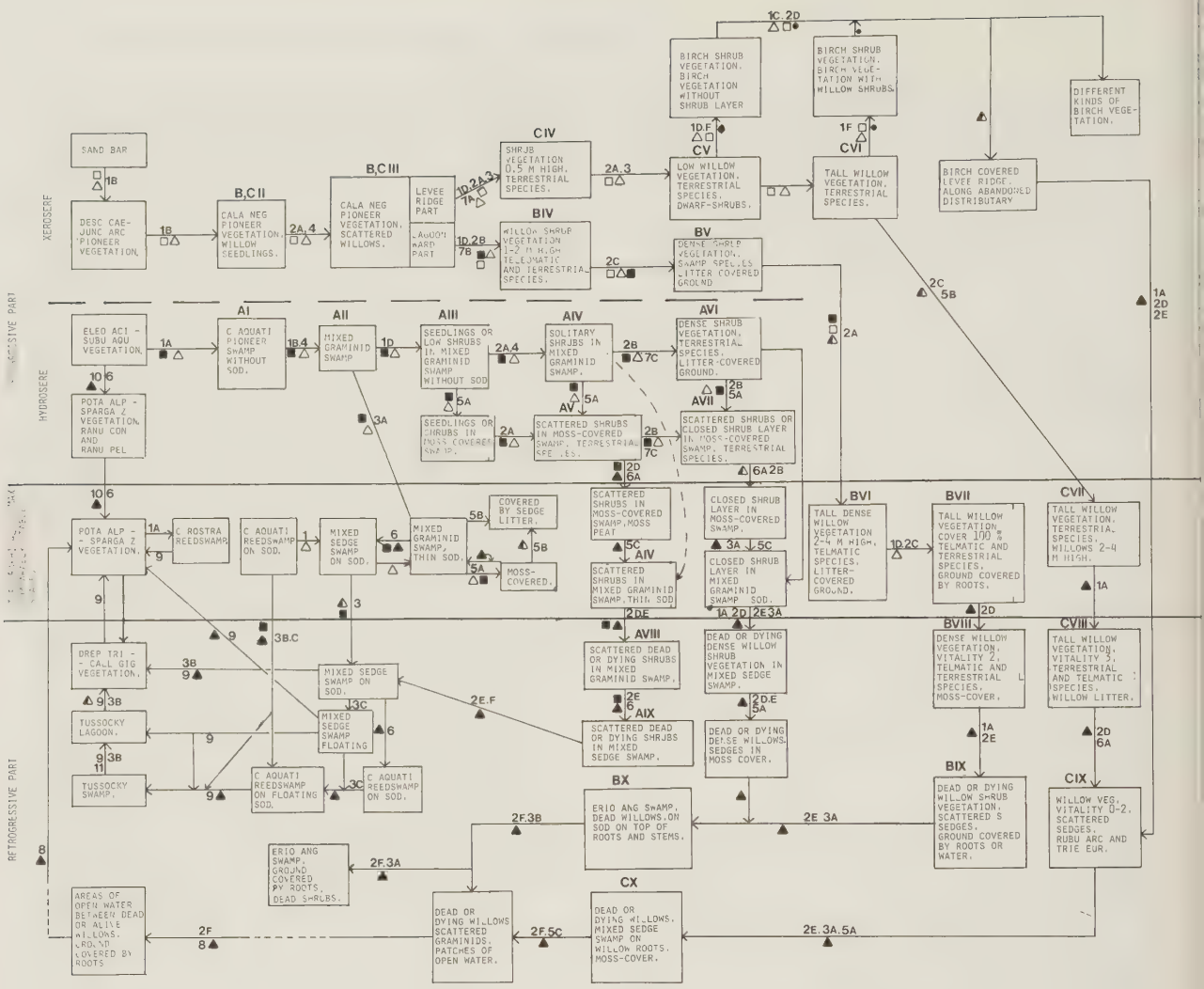

XEROSERE
HYDROSERE
RETROGRESSIVE PART
SAND BAR
DESC CAE-JUNC ARC PIONEER VEGETATION.
CALA NEG PIONEER VEGETATION, WILLOW SEEDLINGS.
CALA NEG PIONEER VEGETATION, SCATTERED WILLOWS.
LEVEE RIDGE PART
LAGOON WARD PART
SHRUB VEGETATION 0.5 M HIGH, TERRESTRIAL SPECIES.
WILLOW SHRUB VEGETATION 1-2 M HIGH, TELEMATIC AND TERRESTRIAL SPECIES.
BIRCH SHRUB VEGETATION, BIRCH VEGETATION WITHOUT SHRUB LAYER
BIRCH SHRUB VEGETATION, BIRCH VEGETATION WITH WILLOW SHRUBS
DIFFERENT KINDS OF BIRCH VEGETATION.
LOW WILLOW VEGETATION, TERRESTRIAL SPECIES, DWARF-SHRUBS.
TALL WILLOW VEGETATION, TERRESTRIAL SPECIES.
BIRCH COVERED LEVEE RIDGE, ALONG ABANDONED DISTRIBUTARY
DENSE SHRUB VEGETATION, SWAMP SPECIES, LITTER COVERED GROUND
ELEO ACI - SUBU AQU VEGETATION.
C AQUATI PIONEER SWAMP WITHOUT SOD.
MIXED GRAMINID SWAMP
SEEDLINGS OR LOW SHRUBS IN MIXED GRAMINID SWAMP WITHOUT SOD
SOLITARY SHRUBS IN MIXED GRAMINID SWAMP.
DENSE SHRUB VEGETATION, TERRESTRIAL SPECIES, LITTER-COVERED GROUND.
POTA ALP - SPARGA L VEGETATION, RANU CON AND RANU PEL
SEEDLINGS OR SHRUBS IN MOSS COVERED SWAMP.
SCATTERED SHRUBS IN MOSS-COVERED SWAMP, TERRESTRIAL SPECIES.
SCATTERED SHRUBS OR CLOSED SHRUB LAYER IN MOSS-COVERED SWAMP, TERRESTRIAL SPECIES.
POTA ALP - - SPARGA Z VEGETATION.
C ROSTRA REEDSWAMP
C AQUATI REEDSWAMP ON SOD.
MIXED SEDGE SWAMP ON SOD.
MIXED GRAMINID SWAMP, THIN SOD.
COVERED BY SEDGE LITTER.
MOSS-COVERED.
SCATTERED SHRUBS IN MOSS-COVERED SWAMP, MOSS PEAT
CLOSED SHRUB LAYER IN MOSS-COVERED SWAMP.
SCATTERED SHRUBS IN MIXED GRAMINID SWAMP, THIN SOD
CLOSED SHRUB LAYER IN MIXED GRAMINID SWAMP SOD.
TALL DENSE WILLOW VEGETATION 2-4 M HIGH, TELMATIC SPECIES, LITTER-COVERED GROUND.
TALL WILLOW VEGETATION COVER 100 % TELMATIC AND TERRESTRIAL SPECIES, GROUND COVERED BY ROOTS.
TALL WILLOW VEGETATION, TERRESTRIAL SPECIES, WILLOWS 2-4 M HIGH.
DREP TRI - - CALL GIG VEGETATION.
MIXED SEDGE SWAMP ON SOD.
TUSSOCKY LAGOON.
MIXED SEDGE SWAMP FLOATING
TUSSOCKY SWAMP.
C AQUATI REEDSWAMP ON FLOATING SOD.
C AQUATI REEDSWAMP ON SOD.
SCATTERED DEAD OR DYING SHRUBS IN MIXED GRAMINID SWAMP.
DEAD OR DYING DENSE WILLOW SHRUB VEGETATION IN MIXED SEDGE SWAMP.
DENSE WILLOW VEGETATION, VITALITY 2, TELMATIC AND TERRESTRIAL SPECIES, MOSS-COVER.
TALL WILLOW VEGETATION, VITALITY 3, TERRESTRIAL AND TELMATIC SPECIES, WILLOW LITTER.
SCATTERED DEAD OR DYING SHRUBS IN MIXED SEDGE SWAMP.
DEAD OR DYING DENSE WILLOWS, SEDGES IN MOSS COVER.
ERIO ANG SWAMP, DEAD WILLOWS ON SOD ON TOP OF ROOTS AND STEMS.
DEAD OR DYING WILLOW SHRUB VEGETATION, SCATTERED SEDGES, GROUND COVERED BY ROOTS OR WATER.
WILLOW VEG, VITALITY 0-2, SCATTERED SEDGES, RUBU ARC AND TRIE EUR.
ERIO ANG SWAMP, GROUND COVERED BY ROOTS, DEAD SHRUBS.
AREAS OF OPEN WATER BETWEEN DEAD OR ALIVE WILLOWS, GROUND COVERED BY ROOTS.
DEAD OR DYING WILLOWS, SCATTERED GRAMINIDS, PATCHES OF OPEN WATER.
DEAD OR DYING WILLOWS, MIXED SEDGE SWAMP ON WILLOW ROOTS, MOSS-COVER.

Fig. 88. Pathways and stages thought to be the main ones for the hydrarch succession in the Laitaure delta.

The generalized scheme has been made by appraisals from the zonation of the vegetation in different lagoons and by comparing the 70 years old photos with the status of the vegetation of today. That is, the vegetation in a certain position in 1974 has been taken as an estimate of the vegetation in the same position in 1904 or 1922. It is in no ways complete. Arrows indicate possible ways for the development. Only the more important processes between the possible stages are shown. No time scales are applied in this scheme. The development between the hydrosere and the xerosere has here been kept apart but there might very well be connections between them, especially from the hydrosere to the xerosere. In many areas the willow vegetation in the interjacent willow subzone and the willow subzone close to the levee crest does not develop into lagoon vegetation (hatched line) but still it can be seen to have occurred in many places in the Laitaure delta (see lower part of the Fig.). The different vegetational stages in Tables 3–5 are indicated. Topographical climax stages are comparatively stable and generally cover large areas.

Autogenic processes forcing the development: 1. Colonization; (1A) predominatly by sedges; (1B) by graminious pioneer species which, for example, create calmer conditions near the ground on bare sand bars; (1C) by terrestrial species; (1D) by willows; (1E) by birches. 2. Development of the willow cover; (2A) growth of willow shrubs; (2B) closing of the shrub layer; (2C) growth of roots and stems along the ground causing a rise of the level of the ground; (2D) decline in vitality of the willow shrubs, less dense willow cover; (2E) death of willow shrubs; (2F) decomposition of willow root and stems and sometimes a removal causing a lowering in ground level. 3. Development of the sod; (3A) development and increase in thickness of a sod; (3B) death of sedges; (3C) formation of marsh gas. 4. Development of the soil, accumulation of humus and mineral nutrients and development of the texture. 5. Development of the bottom layer; (5A) development of a moss layer, possibly also moss peat; (5B) accumulation of litter; (5C) decomposition of litter, moss peat or humus. 6. Disappearance of species groups; (6A) disappearance of terrestrial species.

Allogenic processes forcing the development: 7. Factors connected to exposure; (7A) exposed to distributary flooding: (7B) sheltered from distributary flooding; (7C) lagoon flooding less frequent. 8. Lowering of ground level caused either by compaction, outflow of sediment or erosion of sediment. 9. Ice erosion at break up, mechanical disintegration of sod. 10. Lowered turbidity. 11. Wave erosion.

Open triangle: Level between ground and mean water-level increased, usually due to deposition of sediments. Filled triangle: Level between ground and mean water-level decreased, usually due to a rise in low water-level. Half-filled triangle: Level between ground and mean water level more or less constant. Filled square: Deposited sediments dominated by silt, usually from suspended load. Open square: Deposited sediments sandy, usually deposited from bottom transported load. Filled circle: The influence of wind-blown sediment may be of great importance.

Tables 3–6

Abbreviation of Latin species names according to the RUBIN-system

Generally the 4 first letters of the genus name and the 3 first letters of the species name are used for the abbreviation. A not-defined species of a genus is abbreviated with the 6 first letters in the genus name followed by a Z, (kodlista B3 and M1).

AGRO BOR *Agrostis borealis*
AGRO STO *Agrostis stolonifera*
BART ALP *Bartsia alpina*
BETU PUB *Betula pubescens*
C AQUATI *Carex aquatilis*
C CANESC *Carex canescens*
C ROSTRA *Carex rostrata*
CALA NEG *Calamagrostis neglecta*
CALA PUR *Calamagrostis purpurea*
CALL VER *Callitriche verna*
CALT PAL *Caltha palustris*
CARD NYM *Cardamine nymanii*
CHAM ANG *Chamaenerion angustifolium*[1]
CERA FON *Cerastium fontanum*
DESC CAE *Deschampsia caespitosa*
DESC FLE *Deschampsia flexuosa*
ELEO ACI *Eleocharis acicularis*
EPIL PAL *Epilobium palustre*
EQUI ARV *Equisetum arvense*
EQUI FLU *Equisetum fluviatile*
EQUI PAL *Equisetum palustre*
ERIO ANG *Eriophorum angustifolium*
EUPH FRI *Euphrasia frigida*
FEST OVI *Festuca ovina*
GALI TFI *Galium trifidum*
GALI ULI *Galium uliginosum*
GERA SIL *Geranium silvaticum*
HIPP VUL *Hippuris vulgaris*
JUNI COM *Juniperus communis*
LUZULA Z *Luzula* sp.
LYCO ANN *Lycopodium annotinum*
LYCO SEL *Lycopodium selago*
MELA PRA *Melampyrum pratense*
MELA SIL *Melampyrum silvaticum*
PARN PAL *Parnassia palustris*
PEDI LAP *Pedicularis lapponica*
PEDI SCE *Pedicularis sceptrum-carolinum*
PHLE COM *Phleum commutatum*
PING VUL *Pinguicula vulgaris*
POA/PRA *Poa pratensis* coll.
POTE PAL *Potentilla palustris*
PYRO MIN *Pyrola minor*
PYRO NOR *Pyrola norvegica*[2]
RANU ACR *Ranunculus acris*
RANU RPT *Ranunculus reptans*
RUBU ARC *Rubus arcticus*
SALIX Z *Salix* sp.
SALI LAP *Salix lapponum*
SALI PHY *Salix phylicifolia*
SELA SEL *Selaginella selaginoides*
SOLI VIR *Solidago virgaurea*
STEL CAL *Stellaria calycantha*
STEL LFO *Stellaria longifolia*
SUBU AQU *Subularia aquatica*
TRIE EUR *Trientalis europaea*
VACC MYR *Vaccinium myrtillus*
VACC ULI *Vaccinium uliginosum*
VACC VIT *Vaccinium vitis-idaea*
VAHL ATR *Vahlodea atropurpurea*
VIOL BIF *Viola biflora*
CALL GIG *Calliergon giganteum*
DREP TRI *Drepanocladus trichophyllus*

[1] *Chamaenerion angustifolium* = *Epilobium angustifolium* L.
[2] *Pyrola norvegica* = *P. rotundifolia* var. *norvegica* (Knaben) Hyl.

Tables 3, 4 and 5. Possible successions in the swamp-willow subzone, the interjacent willow subzone and the willow zone close to the levee crest are shown. The tables have been created by linking parts of plots and transects using various parameters: vegetational composition, small square per cent frequency and characteristic cover, surrounding vegetation, position of squares, soil, hydrology of interlevee basin and age of areas. The interpretation of the vegetation in the beginning of the century has been used to judge the development, especially of the retrogressive succession. The successional stages indicated are also shown in Fig. 88.

In some of the transects the squares used are characterized by their position in metres and sometimes by their number. The cover values of transect 33 have been transformed from the 3-graded scale used in the analyses. Characteristic cover value 100 % is shown as 99 %. Values in brackets concern the large plot. Most of the litter recorded in Table 3 is sedge litter. In Tables 4 and 5 willow leaves generally make up the bulk of the litter. In Table 5 (plots 16, 1–10, 1971; and 11–20, 1971) the dead *Pedicularis sceptrum-carolinum* covers 2 %.

Table 3. A succession possible in the swamp-willow subzone. Stages A I–AV II are regarded as progressive and AV III–A IX as retrogressive parts in the succession. The table starts with analyses in the swamp zone where willows grew quite far away from each other. The first part of the table could also be taken as an example of a quite common development of the swamp vegetation from a *Carex aquatilis* dominated vegetation to a mixed graminid swamp characterized by *Poa pratensis* coll. Stage IV shows the vegetation in a mixed graminid swamp with solitary low willow shrubs. Squares from drier sites and squares with a progressively denser shrub layer are then added. Stage V shows willow shrubs in moss covered swamp colonized by a few terrestrial species, and stages VI and VII show different combinations of swamp vegetation with different cover of willow shrubs. Stages VIII and IX show analyses from different parts where willow shrubs are dead or dying. The parts of plots and transects in these stages are arranged towards wetter conditions, lower cover of shrubs, and lower vitality of the willow shrubs.

Table 3.

	PLOT 13						TR 38	PLOT 10				TR 38	PLOT 15					
	1–10	11–20	1–10	11–20	11–20	1–10	105–106 m	1–10	11–20	11–20	1–10	107–109 m	1–10	11–20	1–10	11–20	1–10	11–20
year	71	71	72	72	73	73	72	71	71	74	74	72	71	71	73	73	74	74
number of squares	10	10	10	10	10	10	2	10	10	10	10	4	10	10	10	10	10	10
successional stage	A I				A II		A III						A IV					
willow height							0.6		(0.5)			0.6	0.6	1.2	0.7	1.4	1.0	1.4
willow vitality							3		(3)			3	3	3	3	3	3	3
mosses	100^{24}	100^{29}	100^{8}	100^{12}	100^{20}	100^{15}	100^{99}	100^{56}	100^{59}	100^{82}	100^{73}	100^{75}	100^{78}	100^{82}	100^{80}	100^{82}	100^{86}	100^{77}
litter	.	.	.	.	.	.	100^{20}	100^{15}	100^{12}	100^{11}	100^{23}	100^{23}	100^{2}	100^{3}	100^{3}	100^{4}	100^{7}	100^{18}
Deschampsia caespitosa	100^{4}	90^{5}	30^{2}	50^{2}	20^{1}	40^{1}	.	40^{2}	10^{1}	100^{1}	100^{1}	.	.	.	10^{1}	.	.	20^{1}
Ranunculus reptans	50^{1}	70^{1}	.	.	50^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.
Caltha palustris	90^{1}	80^{2}	100^{1}	80^{1}	100^{3}	100^{2}	50^{1}	100^{7}	100^{16}	100^{11}	100^{12}	100^{4}	30^{1}	40^{1}	30^{1}	20^{1}	50^{1}	20^{1}
Equisetum arvense	40^{1}	40^{1}	.	.	20^{1}	10^{1}	100^{7}	100^{3}	100^{3}	90^{2}	80^{1}	100^{9}	100^{6}	100^{4}	100^{7}	100^{6}	100^{8}	100^{18}
Carex aquatilis	100^{58}	100^{53}	100^{71}	100^{56}	100^{23}	100^{27}	50^{5}	90^{5}	90^{4}	100^{5}	100^{4}	100^{28}	100^{5}	100^{4}	100^{2}	100^{3}	100^{2}	100^{3}
Cardamine nymanii	100^{1}	100^{2}	100^{1}	100^{1}	100^{2}	70^{1}	100^{1}	100^{3}	100^{4}	70^{2}	80^{2}	100^{3}	80^{1}	70^{1}	80^{1}	60^{1}	50^{1}	70^{1}
Epilobium palustre	.	20^{1}	.	.	.	.	50^{1}	100^{3}	90^{2}	100^{1}	30^{1}	25^{1}	100^{1}	100^{2}	90^{1}	100^{1}	100^{1}	90^{1}
Poa pratensis coll.	.	10^{1}	20^{1}	40^{1}	100^{10}	70^{5}	50^{1}	100^{5}	100^{4}	100^{19}	100^{16}	100^{28}	100^{3}	100^{2}	100^{9}	100^{14}	100^{2}	100^{6}
Eriophorum angustifolium	.	.	10^{2}	.	10^{1}	30^{3}	.	.	.	.	.	.	.	.	.	.	.	.
Carex canescens	.	.	.	.	30^{1}	20^{2}	50^{1}	100^{4}	60^{7}	100^{3}	100^{3}	100^{1}	60^{1}	90^{1}	100^{4}	90^{2}	100^{4}	100^{3}
Agrostis stolonifera	.	.	.	.	.	.	50^{1}	.	.	.	.	25^{1}	.	.	.	.	.	.
Calamagrostis neglecta	.	.	.	.	.	.	.	10^{3}	40^{1}	100^{1}	100^{1}	.	10^{1}	.	.	.	40^{1}	10^{1}
Salix spp. coll.	.	.	.	.	.	.	100^{55}	.	.	.	.	50^{20}	70^{3}	80^{36}	40^{12}	90^{37}	50^{14}	90^{46}
Calamagrostis purpurea	.	.	.	.	.	.	50^{1}	.	.	.	.	.	.	.	.	.	20^{1}	.
Galium trifidum	.	.	.	.	.	.	.	10^{5}	20^{2}	10^{1}	40^{1}	50^{1}	100^{2}	90^{2}	90^{1}	60^{1}	90^{1}	60^{1}
Equisetum fluviatile	.	.	.	.	.	.	.	100^{38}	100^{44}	100^{10}	100^{14}	.	.	.	20^{1}	30^{1}	20^{1}	40^{1}
Carex rostrata	.	.	.	.	.	.	.	.	.	.	.	75^{5}	.	.	.	.	.	.
Equisetum variegatum	.	.	.	.	.	.	.	.	.	.	.	75^{1}	.	.	.	.	.	.
Pyrola minor	.	.	.	.	.	.	.	.	.	.	.	.	10^{1}	.	.	.	.	.
Solidago virgaurea	.	.	.	.	.	.	.	.	.	.	.	.	10^{1}	10^{1}	10^{1}	.	10^{1}	10^{1}
Phleum commutatum	.	.	.	.	.	.	.	.	.	.	.	.	50^{1}	70^{2}	30^{1}	10^{1}	.	30^{1}
Luzula spp.	.	.	.	.	.	.	.	.	.	.	.	.	100^{3}	100^{3}	70^{2}	80^{2}	60^{1}	40^{1}
Parnassia palustris	.	.	.	.	.	.	.	.	.	.	.	.	10^{1}	.	.	.	.	.
Pedicularis sceptrum-car.	.	.	.	.	.	.	.	.	.	.	.	.	80^{3}	90^{2}	70^{2}	90^{2}	70^{1}	40^{2}
Stellaria calycantha	.	.	.	.	.	.	.	.	.	.	.	.	30^{3}	40^{3}	20^{1}	.	30^{1}	.
Festuca ovina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polygonum viviparum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10^{1}	.
Equisetum palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viola biflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubus arcticus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 3 (contin.)

	PLOT 9				TR 12		PLOT 19			TR 23						TR 21			TR 33	
	1-10	11-20	11-20	1-10	1-4	1-4	5-20	5-20	5-20	18-19	22-23	24.5-26	26-30	30-34.5	34.5-41	34-39	39-42	42-59	43-62	116-119
year	71	71	74	74	70	71	71	73	74	72	72	72	72	72	72	72	72	72	72	72
number of squares	10	10	10	10	4	4	16	16	16	4	4	6	8	9	13	10	6	34	20	4
successional stage	A V				A IV		A VII			A XIII						A IX			A X	
willow height	1.0	1.0	0.5	1.0	1.7	1.7	1.5	1.5	1.5	1.2	1.0	1.4	0.7	0.9	0.6	0.6	0.6	0.6	0.3	0.4
willow vitality	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	1	0	0	1
mosses	100^{23}	100^{26}	100^{66}	100^{61}	100^{63}	100^{54}	100^{99}	100^{60}	100^{76}	100^{70}	100^{50}	100^{22}	100^{38}	100^{40}	100^{60}	40^{17}	.	.	45^{1}	.
litter	.	.	80^{7}	.	100^{15}	100^{30}	100^{11}	100^{29}	100^{25}	100^{28}	100^{45}	100^{17}	.	.	.	.	.	.	.	.
DESC CAE	.	.	.	.	.	.	.	.	44^{1}	.	.	.	.	.	.	.	.	.	.	.
RANU RPT	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50^{11}	17^{1}	.	.	25^{6}
CALT PAL	20^{3}	30^{3}	70^{3}	30^{2}	.	25^{1}	.	.	.	50^{1}	.	50^{1}	63^{1}	44^{1}	31^{1}	.	.	.	.	.
EQUI ARV	100^{15}	100^{17}	100^{6}	100^{16}	100^{23}	100^{10}	100^{23}	100^{13}	88^{1}	75^{4}	.	.	.	.	.	90^{1}	.	.	.	.
C AQUATI	100^{6}	100^{5}	100^{6}	100^{8}	100^{20}	100^{12}	.	6^{1}	.	.	.	83^{10}	100^{30}	100^{23}	100^{17}	60^{13}	100^{20}	100^{30}	100^{51}	100^{25}
CARD NYM	100^{1}	100^{3}	100^{3}	100^{1}	100^{1}	50^{1}	.	.	.	100^{1}	67^{1}	67^{1}	100^{1}	100^{1}	77^{1}	20^{1}	.	.	.	.
EPIL PAL	100^{6}	100^{7}	100^{2}	100^{1}	25^{1}	.	100^{2}	100^{1}	75^{1}	25^{1}	.	50^{1}	63^{1}	11^{1}	.	.	.	.	15^{1}	.
POA/PRA	100^{23}	100^{27}	100^{22}	100^{19}	.	.	.	.	.	.	50^{1}	.	100^{1}	100^{3}	100^{2}	.	.	.	.	.
ERIO ANG	.	.	.	.	.	.	.	.	.	.	.	.	.	33^{1}	15^{1}	20^{1}	.	6^{1}	20^{3}	.
C CANESC	70^{3}	100^{6}	100^{5}	100^{4}	.	.	.	.	.	.	.	83^{1}	100^{2}	100^{1}	100^{1}	60^{3}	33^{1}	6^{1}	.	.
AGRO STO	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CALA NEG	100^{2}	90^{3}	100^{2}	100^{1}	.	75^{1}	19^{1}	31^{1}	.	25^{1}	.	.	.	.	.	.	.	.	5^{1}	.
SALIX Z	.	.	40^{1}	50^{1}	100^{75}	100^{41}	100^{77}	100^{65}	100^{76}	100^{95}	100^{89}	100^{53}	63^{35}	78^{48}	100^{52}	100^{16}	100^{6}	100^{4}	60^{21}	100^{42}
CALA PUR	.	.	.	.	.	.	.	.	.	100^{1}	33^{1}	67^{1}	100^{1}	100^{1}	100^{1}	100^{4}	50^{1}	6^{1}	5^{1}	.
GALI TFI	40^{3}	50^{2}	80^{1}	60^{1}	.	.	.	.	.	100^{1}	.	33^{1}	63^{1}	11^{1}	.	.	.	.	.	.
EQUI FLU	80^{2}	80^{2}	100^{1}	100^{1}	.	.	.	.	.	59^{1}	100^{4}	100^{4}	100^{6}	100^{24}	100^{20}	.	.	.	.	100^{11}
C ROSTRA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40^{4}	100^{53}	100^{60}	100^{45}	100^{43}
EQUI VAR	.	.	.	.	.	.	6^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.
PYRO MIN	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SOLI VIR	.	.	.	.	.	.	.	.	.	25^{1}	.	.	.	.	.	.	.	.	.	.
PHLE COM	20^{2}	50^{1}	70^{1}	80^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
LUZU LAZ	10^{2}	.	.	50^{1}	.	.	25^{1}	6^{1}	13^{1}	.	.	.	.	.	.	.	.	.	.	.
PARN PAL	.	.	.	.	25^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PEDI SCE	.	.	20^{1}	20^{1}	75^{10}	100^{17}	.	.	.	.	.	.	.	.	.	.	.	.	.	.
STEL CAL	.	30^{1}	40^{1}	40^{2}	.	.	25^{1}	63^{1}	19^{1}	.	.	.	.	.	.	.	.	.	.	.
FEST OVI	10^{1}	.	20^{2}	20^{2}	.	.	6^{1}	.	6^{1}	.	.	.	.	.	.	.	.	.	.	.
POLY VIV	.	.	.	10^{1}	25^{1}	50^{1}	.	6^{1}	6^{1}	.	.	.	.	.	.	.	.	.	.	.
EQUI PAL	.	.	.	.	.	.	.	.	.	50^{2}	100^{1}	83^{1}	.	11^{1}	31^{1}	.	.	.	.	.
VIOL BIF	.	.	.	.	.	.	13^{1}	6^{2}	13^{1}	.	.	.	.	.	.	.	.	.	.	.
RUBU ARC	.	.	.	.	.	.	69^{5}	81^{3}	75^{2}	.	.	.	.	.	.	.	.	.	.	.

Table 4. A succession possible in the interjacent willow subzone.

Stages B II–B VI are regarded as progressive and B VII–B X as retrogressive parts in the succession. The table starts with analyses of pioneer vegetation dominated by *Calamagrostis neglecta* with a high frequency of willow seedlings or in some places shoots from buried parts of willows (B II). Analyses of successively drier and older areas are added. The succession shown in the beginning of the table until belt-transect 12 squares 5–12, has been regarded as common for both the development of the interjacent willow subzone and the willow zone close to the levee crest (see Table 5). But following this kind of vegetation there is usually a differentiation of the vegetation along the levee crest (see Table 5). Stage B III is characterized by low willow pioneer vegetation which covers large areas at the delta front. Stage B IV shows the vegetation where the willow shrub layer is dense and about 1.5–2 m high. Stage B V represents the vegetation in a comparatively young area with a very dense shrub layer and a sparse field layer. In stage B VI the vegetation is regarded as older but not influenced to any greater extent by a raised low water-level. In stages B VIII–B X squares are linked which are situated in progressively wetter conditions and in stage B IX and B X the ground is covered by water and the shrubs are dead or dying. All squares in this part of the table are situated in interlevee basins with low water thresholds.

Table 4.

	PLOT 4								TR 12								TR 22
	1–10	11–20	11–20	1–10	1–10	11–20	1–10	11–20	45–54	45–54	33–44	33–44	21–32	21–32	13–20	13–20	0–4
year	71	71	72	72	73	73	74	74	70	71	70	71	70	71	70	71	72
number of squares	10	10	10	10	10	10	10	10	10	10	12	12	12	12	8	8	8
successional stage	B II (C II)										B III (C III)						
willow vitality	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
mosses	100^{65}	100^{73}	100^{98}	100^{98}	100^{95}	100^{60}	100^{54}	100^{54}	.	100^{74}	25^{21}	83^{22}	50^{17}	100^{24}	100^{13}	100^{17}	100^{1}
litter	.	.	.	.	.	.	.	.	.	100^{5}	100^{20}	100^{20}	100^{10}	100^{20}	100^{20}	100^{10}	100^{10}
Deschampsia caespitosa	.	.	10^{1}	.	10^{1}	.	10^{1}	30^{1}	.	.	.	.	.	.	.	.	.
Juncus arcticus	10^{1}	10^{2}	50^{1}	10^{1}	10^{1}	50^{1}	30^{3}	10^{1}	10^{1}	.	.	.	.	33^{1}	.	.	.
Polygonum viviparum	.	.	.	10^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.
Parnassia palustris	.	.	.	10^{1}	.	.	10^{1}	.	.	.	17^{1}	.	.	.	.	.	.
Euphrasia frigida	.	.	.	.	.	10^{1}	.	100^{2}	40^{1}	20^{1}	8^{1}	.	17^{1}	8^{1}	.	.	.
Festuca ovina	.	.	.	.	.	.	.	.	.	.	8^{3}	8^{5}	.	.	.	.	.
Alchemilla vulgaris	.	.	.	.	.	.	.	.	.	.	8^{1}	8^{1}	.	.	.	.	.
Ranunculus acris	.	.	.	.	.	.	.	.	.	.	25^{2}	17^{1}	.	.	.	.	.
Luzula spp. coll.	.	.	.	.	.	.	.	.	.	.	25^{1}	33^{1}	.	17^{1}	.	13^{1}	.
Corallorhiza trifida	.	.	.	.	.	.	.	.	.	.	.	.	8^{1}	.	.	.	.
Stellaria longifolia	.	.	.	.	.	.	.	.	.	.	.	.	8^{1}	.	.	.	.
Astragalus alpinus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13^{1}	.	.
Agrostis borealis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38^{1}
Pyrola minor	.	.	.	.	.	.	.	.	.	.	.	17^{2}	17^{1}	25^{1}	25^{1}	13^{1}	13^{1}
Betula (juv.)	.	40^{1}	70^{1}	80^{1}	.	10^{1}	.	.	.	10^{1}	.	.	17^{1}	18^{1}	.	.	.
Pedicularis sceptrum car.	10^{1}	.	50^{1}	10^{1}	.	70^{1}	30^{1}	70^{1}	40^{3}	90^{1}	83^{8}	92^{5}	100^{20}	100	100^{24}	100^{31}	75^{22}
Cardamine nymanii	.	.	.	.	.	.	.	.	.	.	17^{1}	17^{1}	17^{1}	.	75^{1}	38^{1}	.
Caltha palustris	.	.	.	.	.	.	.	.	.	.	.	8^{1}	.	.	.	.	.
Epilobium palustre	.	.	.	.	.	.	.	.	.	.	.	.	8^{1}	17^{1}	.	.	.
Poa pratensis coll.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13^{1}	.	38^{1}
Galium trifidum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus reptans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum palustre	.	.	.	.	.	.	10^{1}	.	.	.	.	.	.	.	.	.	.
Calamagrostis purpurea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex canescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubus arcticus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solidago virgaurea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Melampyrum silvaticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trientalis europaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stellaria calycantha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Juniperus (juv.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum fluviatile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex rostrata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla palustris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eriophorum angustifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hippuris vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis neglecta	10^{24}	100^{19}	100^{20}	100^{16}	100^{4}	100^{3}	100^{6}	100^{4}	.	.	50^{2}	100^{1}	.	100^{1}	.	.	100^{1}
Carex aquatilis	.	40^{2}	60^{1}	10^{1}	10^{1}	80^{1}	10^{1}	80^{2}	100^{7}	100^{4}	100^{6}	100^{6}	100^{8}	100^{9}	100^{18}	100^{10}	100^{2}
Equisetum arvense	100^{14}	100^{31}	100^{15}	100^{6}	100^{9}	100^{12}	100^{13}	100^{19}	100^{3}	100^{4}	100^{12}	100^{8}	100^{8}	100^{13}	100^{28}	100^{16}	100^{35}
Salix spp. (juv.)	100^{3}	100^{3}	100^{7}	100^{5}	100^{7}	100^{10}	100^{10}	100^{25}	.	.	.	.	.	.	.	.	.
Salix spp.	.	.	.	.	.	.	.	.	100^{59}	100^{54}	92^{47}	100^{38}	75^{43}	92^{34}	100^{71}	100^{48}	100^{49}

Table 4 (contin.)

	TR 21			TR 4		TR 11	TR 21	TR 33		TR 11	TR 21		TR 33
	20–22	22–23.5	23.5–24	18–24	18–24	1–6	25–27	13–22	23–42	1–6	27–29	29–34	131–136
year	72	72	72	70	71	70	72	72	72	74	72	72	72
number of squares	8	6	6	7	7	6	8	10	20	6	8	20	6
successional stage	B VII			B VIII						B IX			B X
willow vitality	3	3	2	3	3	2	2–0	0	0	0–1	0–1	0–1	0
mosses	88^{32}	100^{6}	100^{16}	100^{53}	100^{54}	100^{12}	.	90^{53}	100^{57}	.	38^{7}	.	17^{2}
litter	100^{30}	100^{50}	100^{60}	100^{43}	100^{36}	100^{20}	.	.	.	.	.	.	.
DESC CAE	.	.	.	.	.	.	.	.	.	.	.	.	.
JUNC ARC	.	.	.	.	.	.	.	.	.	.	.	.	.
POLY VIV	.	.	.	.	.	.	.	.	.	.	.	.	.
PARN PAL	.	.	.	.	.	.	.	.	.	.	.	.	.
EUPH FRI	.	.	.	.	.	.	.	.	.	.	.	.	.
FEST OVI	.	.	.	.	.	.	.	.	.	.	.	.	.
ALCH VUL	.	.	.	.	.	.	.	.	.	.	.	.	.
RANU ACR	.	17^{1}	.	.	.	.	.	.	.	.	.	.	.
LUZULA Z	.	.	.	.	.	.	.	.	.	.	.	.	.
CORA TRI	.	.	.	.	.	.	.	.	.	.	.	.	.
STEL LON	.	.	.	.	.	.	.	.	.	.	.	.	.
ASTR ALP	.	.	.	.	.	.	.	.	.	.	.	.	.
AGRO BOR	.	.	.	.	.	.	.	.	.	.	.	.	.
PYRO MIN	.	.	.	.	.	.	.	.	.	.	.	.	.
BETULA (juv.)	.	.	.	.	.	.	.	.	18^{1}	30^{1}	.	.	.
PEDI SCE	.	.	.	.	.	.	.	.	.	.	.	.	.
CARD NYM	75^{2}	100^{1}	100^{2}	.	14^{1}	.	100^{1}	40^{1}	.	17^{1}	38^{1}	.	17^{1}
CALT PAL	.	.	.	.	14^{1}	.	.	.	.	.	.	.	.
EPIL PAL	.	.	56^{1}	.	.	.	13^{1}	30^{1}	100^{3}	.	25^{1}	.	.
POA/PRA	.	.	.	.	.	.	.	.	.	.	.	.	.
GALI TFI	50^{1}	50^{1}	83^{1}	.	.	.	100^{1}	30^{1}	.	.	50^{1}	.	.
RANU RPT	.	25^{1}	17^{1}	.	.	14^{1}	100^{25}	.	.	.	.	20^{1}	.
EQUI PAL	.	.	.	.	14^{1}	.	.	.	.	.	.	.	.
CALA PUR	25^{1}	17^{1}	.	.	.	.	100^{4}	90^{12}	10^{1}	.	88^{1}	100^{2}	.
C CANESC	13^{1}	.	.	29^{6}	86^{2}	33^{4}	75^{10}	60^{7}	90^{7}	67^{2}	13^{5}	20^{3}	.
RUBU ARC	.	.	17^{1}	.	.	.	.	.	.	.	.	.	.
SOLI VIR	.	.	.	.	.	.	.	.	.	.	.	.	.
MELA SIL	.	.	.	.	.	.	.	.	.	.	.	.	.
TRIE EUR	.	.	.	.	.	.	33^{1}	.	.	.	.	.	.
STEL CAL	.	.	.	.	.	.	.	.	.	.	.	.	.
JUNIPERUS (juv.)	.	.	.	.	.	.	.	.	.	.	.	.	.
EQUI FLU	.	.	.	14^{2}	.	67^{3}	.	.	100^{1}	.	.	.	100^{27}
C ROSTRA	.	.	.	.	.	100^{23}	.	20^{5}	100^{15}	100^{3}	.	.	100^{37}
POTE PAL	.	.	.	.	.	83^{6}	.	.	.	83^{8}	.	.	.
ERIO ANG	.	.	.	.	.	.	25^{6}	.	.	.	50^{4}	.	.
HIPP VUL	.	.	.	.	.	.	.	.	.	.	38^{5}	70^{18}	.
CALA NEG	25^{1}	.	.	.	.	.	.	20^{25}	85^{1}	.	.	.	.
C AQUATIL	38^{1}	.	.	80^{4}	80^{12}	100^{18}	63^{3}	100^{47}	100^{50}	100^{19}	.	.	100^{10}
EQUI ARV	88^{39}	100^{12}	100^{11}	57^{5}	86^{2}	33^{2}	75^{2}	20^{1}	5^{1}	.	.	.	.
SALIX Z (dead)	.	.	.	.	.	.	.	80^{33}	100^{37}	83^{8}	.	.	83^{38}
SALIX Z	88^{86}	83^{99}	100^{73}	100^{67}	100^{75}	100^{57}	89^{51}	70^{10}	15^{5}	50^{28}	13^{5}	40^{9}	.

Table 4 (contin.)

	TR 12		TR 22				TR 4				TR 22		TR 38	TR 23				
	5–12	5–12	4–6	6–10.5	10.5–14	14–19	25–29	25–29	12–17	12–17	20–22	22–27.5	103–105	5–7	7–8	7–9	10–11	12–14
year	70	71	72	72	72	72	70	71	70	71	72	72	72	72	72	72	72	72
number of squares	8	8	4	9	7	10	5	5	6	6	6	11	4	7	5	8	4	8
Successional stage	B IV						B V							B VI				
willow vitality	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2–1	3	3	3
mosses	100^{16}	100^{23}	100^{5}	100^{1}	100^{54}	100^{79}	100^{54}	100^{48}	100^{40}	100^{54}	100^{17}	100^{17}	100^{99}	100^{1}	100^{1}	100^{60}	100^{80}	100^{90}
litter	100^{10}	100^{20}	100^{20}	100^{81}	100^{26}	100^{10}	100^{40}	100^{42}	100^{22}	100^{33}	100^{70}	100^{70}	25^{13}	100^{97}	100^{98}	100^{39}	100^{18}	100^{7}
DESC CAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
JUNC ARC	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
POLY VIV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PARN PAL	.	13^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
EUPH FRI	38^{1}	13^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
FEST OVI	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
ALCH VUL	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
RANU ACR	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
LUZULA Z	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25^{1}
CORA TRI	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
STEL LON	.	.	.	67^{1}	14^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.
ASTR ALP	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
AGRO BOR	.	.	25^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PYRO MIN	38^{1}	.	.	.	.	.	.	.	.	.	.	.	.	43^{1}	.	.	.	.
BETULA (juv.)	13^{1}	13^{1}	.	.	.	.	.	.	.	.	.	.	.	57^{1}	20^{1}	25^{1}	.	.
PEDI SCE	75^{17}	88^{19}	100^{45}	67^{20}	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CARD NYM	75^{2}	25^{1}	.	.	71^{1}	70^{1}	.	.	50^{1}	50^{1}	33^{1}	55^{1}	100^{1}	.	.	.	50^{1}	88^{3}
CALT PAL	.	.	.	44^{1}	14^{1}	.	.	.	.	.	.	.	100^{1}	.	.	.	.	.
EPIL PAL	25^{1}	.	100^{1}	100^{1}	43^{1}	40^{1}	.	.	.	.	.	.	.	14^{1}	19^{1}	.	63^{1}	38^{1}
POA/PRA	.	.	50^{1}	56^{1}	70^{1}	100^{1}	.	.	.	.	50^{1}	.	.	14^{1}	.	.	75^{1}	100^{1}
GALI TFI	.	.	100^{1}	44^{1}	37^{1}	60^{1}	.	.	.	.	.	.	.	.	.	13^{1}	50^{1}	75^{1}
RANU RPT	.	.	.	.	29^{1}	10^{1}	.	.	.	.	.	.	.	.	.	.	.	.
EQUI PAL	.	.	.	.	.	.	.	.	.	17^{1}	.	.	.	.	.	.	.	13^{1}
CALA PUR	.	.	.	.	29^{1}	70^{1}	.	.	.	.	17^{1}	11^{1}	.	.	.	.	.	25^{1}
C CANESC	.	.	.	.	.	.	60^{1}	.	.	.	.	.	.	.	.	.	.	.
RUBU ARC	.	.	.	.	.	.	.	.	.	.	.	.	.	29^{1}	100^{2}	100^{11}	100^{24}	63^{7}
SOLI VIR	.	.	.	.	.	.	.	.	.	.	.	.	.	14^{1}	.	.	.	.
MELA SIL	.	.	.	.	.	.	.	.	.	.	.	.	.	100^{1}	100^{1}	38^{1}	50^{1}	/
TRIE EUR	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14^{1}	.	.	.
STEL CAL	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13^{1}	75^{1}	100^{1}	25^{1}
JUNIPERUS (juv.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20^{1}	.	.
EQUI FLU	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C ROSTRA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
POTE PAL	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
ERIO ANG	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
HIPP VUL	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CALA NEG	.	.	.	.	.	60^{1}	.	.	.	.	38^{1}	.	.	14^{1}	20^{1}	.	13^{1}	75^{1}
C AQUATIL	100^{45}	100^{20}	50^{2}	78^{2}	100^{3}	100^{28}	80^{3}	100^{2}	83^{2}	83^{4}	100^{5}	91^{1}	.	29^{5}	100^{1}	25^{3}	.	50^{1}
EQUI ARV	100^{24}	100^{9}	100^{58}	100^{90}	100^{40}	100^{13}	100^{2}	80^{3}	83^{3}	83^{4}	100^{7}	100^{5}	100^{2}	100^{54}	100^{52}	100^{10}	100^{45}	100^{1}
SALIX (juv.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SALIX Z	50^{28}	50^{9}	100^{58}	100^{76}	100^{97}	100^{80}	100^{90}	100^{84}	100^{68}	100^{45}	100^{99}	100^{95}	100^{38}	100^{86}	100^{64}	100^{65}	100^{99}	100^{57}

Table 5. A succession possible in the willow subzone close to the levee crest.

Stages C II–C VIII are regarded as progressive and C IX–C X as retrogressive parts in the succession. Stages C II and C III are also found in Table 4. The topography in the young parts of the delta is not developed and almost the same vegetation may be found along the whole gradient from the levee crest to the swamp-willow subzone. The difference in the vegetation is very small and difficult to determine. The gradient may be divided according to the development of land, the distributary passing and the soil development. Stages IV and V show low willow pioneer vegetation at increasing age and where scattered birch shrubs may be found. Stage VI is an example of the vegetation in an area with very dense shrub layer with solitary birches and stage VII of the vegetation in a drier area but with equally dense willow cover. Stages VIII–X are linked towards wetter conditions. The squares may represent different successional stages but they may also be looked upon as examples of different retrogressive vegetation types derived from the drier parts of the delta. Stage X shows the vegetation in an old narrow levee with dead birches in a lagoon with a very high low water threshold.

Table 5.

	PLOT 5								PLOT 16						PLOT 19		
	1-10	11-20	11-20	1-10	11-20	11-20	1-10	1-10	1-10	11-20	1-10	11-20	1-10	11-20	1-10	1-10	1-10
year	71	71	72	72	73	74	73	74	71	71	73	73	74	74	71	73	74
number of squares	10	10	10	10	10	10	10	10	10	10	10	10	10	10	4	4	4
successional stage	C IV								C V						C VI		
willow vitality	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
mosses	100^{40}	100^{70}	100^{74}	100^{38}	100^{99}	100^{99}	100^{70}	100^{57}	100^{49}	100^{39}	100^{73}	100^{62}	100^{57}	100^{59}	100^{99}	100^{38}	100^{70}
litter	100^{62}	100^{21}	100^{26}	100^{62}	90^{5}	20^{3}	100^{24}	100^{10}	100^{31}	100^{29}	100^{1}	100^{23}	100^{22}	100^{13}	100^{15}	100^{5}	100^{30}
Deschampsia caespitosa	.	.	.	10^{1}	80^{1}	80^{1}	100^{1}	80^{1}	.	.	60^{1}	10^{1}	70^{1}	100^{1}	.	.	.
Juncus arcticus	40^{1}	20^{1}	30^{1}	30^{1}	40^{1}	20^{1}	30^{1}	40^{1}	60^{2}	10^{2}	60^{1}	10^{1}	60^{1}	10^{1}			
Polygonum viviparum	.	10^{1}	10^{1}	.	10^{1}	10^{1}	.	.	.	10^{1}	.	10^{1}	.	10^{1}	.	.	.
Parnassia palustris	.	.	10^{1}	40^{1}	10^{1}	10^{1}	30^{1}	60^{1}	100^{2}	100^{1}	100^{1}	100^{1}	100^{1}	100^{1}	.	.	.
Euphrasia frigida	.	.	.	10^{1}	.	.	20^{1}	30^{1}	70^{1}	30^{1}	50^{1}	80^{1}	100^{2}	.	.	.	.
Festuca ovina	50^{1}	20^{1}	.	50^{1}	.	.	50^{1}	50^{1}	10^{1}	20^{3}	40^{1}	50^{1}	70^{1}	70^{1}	.	.	.
Alchemilla vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus acris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzula spp.	.	.	20^{2}	.	20^{2}	30^{1}	.	10^{1}	20^{1}	10^{1}	70^{1}	50^{1}	90^{1}	40^{1}	.	.	.
Corallorhiza trifida	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stellaria longifolia	63^{1}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalus alpinus	.	.	.	.	.	10^{1}	.	.	.	.	.	.	.	.	.	.	.
Agrostis borealis	20^{1}	.	.	40^{1}	20^{1}	10^{1}	70^{1}	30^{1}	100^{6}	100^{6}	100^{4}	100^{5}	100^{3}	100^{3}	.	.	.
Pylola minor	90^{1}	70	10^{1}	70^{1}	.	10^{1}	70^{1}	90^{1}	.	60^{1}	10^{1}	.	10^{1}	10^{1}	.	.	.
Betula (juv.)	30^{1}	.	40^{1}	100^{1}	10^{1}	.	40^{1}	40^{1}	.	.	.	50^{1}	30^{1}	40^{1}	.	.	.
Pedicularis sceptrum car.	100^{10}	100^{18}	100^{12}	100^{8}	100^{5}	100^{5}	100^{4}	100^{5}	100^{4}	100^{3}	100^{2}	70^{1}	100^{3}	70^{1}	.	.	.
Cardamine nymanii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Caltha palustris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Epilobium palustre	.	.	.	10^{1}	.	20^{1}	10^{1}	10^{1}	50^{1}	80^{1}	50^{1}	70^{1}	70^{1}	90^{1}	100^{2}	100^{1}	100^{1}
Poa pratensis coll.	.	.	.	.	.	.	.	10^{1}	.	60^{1}	70^{1}	20^{1}	10^{1}	.	.	.	.
Galium trifidum	.	.	.	.	.	.	.	.	.	.	10^{1}	10^{1}	.	.	.	.	.
Ranunculus reptans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis purpurea	.	.	.	.	.	.	.	10^{1}	.	.	.	.	.	.	.	.	.
Carex canescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rubus arcticus	.	.	.	.	.	.	.	.	.	.	.	.	10^{1}	.	100^{3}	100^{2}	100^{2}
Solidago virgaurea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25^{1}	.
Melampyrum silvaticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trientalis europaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stellaria calycantha	.	.	.	.	.	.	.	.	10^{1}	.	20^{1}	.	10^{1}	.	.	50^{1}	25^{1}
Juniperus (juv.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Equisetum fluviatile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex rostrata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla palustris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eriophorum angustifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hippuris vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Calamagrostis neglecta	80^{1}	70^{1}	100^{1}	100^{1}	100^{1}	100^{1}	100^{1}	100^{1}	80^{1}	90^{1}	40^{1}	60^{1}	.	30^{1}	.	.	.
Carex aquatilis	100^{4}	100^{5}	100^{6}	100^{5}	100^{3}	100^{3}	100^{3}	100^{4}	10^{1}	10^{1}	20^{1}	10^{1}	10^{1}	.	.	.	.
Equisetum arvense	100^{3}	100^{4}	100^{3}	100^{2}	100^{2}	100^{2}	100^{3}	100^{2}	100^{9}	100^{8}	100^{13}	100^{10}	100^{8}	100^{4}	100^{20}	100^{18}	50^{1}
Salix sp. (juv.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix spp.	100^{37}	100^{22}	100^{35}	100^{30}	100^{24}	100^{33}	100^{30}	100^{45}	100^{44}	100^{37}	100^{31}	100^{23}	100^{44}	100^{48}	100^{74}	100^{65}	100^{65}
Phleum commutatum	.	.	.	.	10^{1}	10^{1}	.	.	.	10^{1}	40^{1}	20^{2}	20^{1}	40^{1}	.	.	17^{1}
Empetrum hermafroditum	.	.	.	10^{1}	.	.	10^{1}	.	.	.	.	.	.	.	.	.	.
Vaccinium myrtillus	.	.	.	.	.	.	10^{1}	.	.	.	.	.	.	.	.	.	.
Lycopodium annotinum	.	.	.	.	.	.	.	.	20^{1}	30^{1}	.	.	.	.	.	.	.
Vahlodea atropurpurea	.	.	.	.	.	.	.	.	.	.	20^{1}	.	.	60^{1}	.	.	.
Vaccinium uliginosum	.	.	.	.	.	.	.	.	.	.	.	10^{1}	.	.	.	.	.
Deschampsia flexuosa	.	.	.	.	.	.	.	.	.	.	.	.	10^{1}	.	.	.	.
Pinguicula vulgaris	.	.	.	.	.	.	.	.	.	10^{5}	.	10^{2}	.	10^{3}	.	.	.
Betula verrucosa	.	.	.	.	.	.	.	.	10^{20}	.	10^{20}	.	10^{20}	.	25^{30}	25^{30}	25^{30}
Geranium silvaticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pedicularis lapponica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

information: Carex aquatilis, in plot 16 1-10, 11-20,1971 and 11-20, 1974 are dead.

Table 5 (contin.)

	TR 4		TR 23	TR 11	TR 33	TR 11	TR 24		TR 33	
	30–34	30–34	4	7–12	2–12	7–12	4–5	6–7	121–126	127–130
year	70	71	72	70	72	74	72	72	72	72
number of squares	5	5	4	6	11	6	8	8	6	4
successional stage	C VII		C VIII		C IX		C X			
willow vitality		2	2	3	1–0	2–0	0	0	0	0
mosses	100^{10}	100^{30}	100^{2}	100^{37}	.	.	100^{63}	100^{20}	33^{99}	100^{35}
litter	100^{99}	100^{63}	100^{93}	100^{30}	.	.	.	.	.	.
DESC CAE	.	.	.	.	.	.	.	.	.	.
JUNC ARC	.	.	.	.	.	.	.	.	.	.
POL VIV	.	.	.	.	.	.	.	.	.	.
PARN PAL	.	.	.	.	.	.	.	.	.	.
EUPH FRI	.	.	.	.	.	.	.	.	.	.
FEST OVI	17^{1}	17^{16}	.	.	.	.	.	.	.	.
ALCH VUL	.	.	.	.	.	.	.	.	.	.
RANU ACR	.	.	.	.	.	.	.	.	.	.
LUZULA Z	.	.	.	.	.	.	.	.	.	.
CORD TRI	.	.	.	.	.	.	.	.	.	.
STEL LON	.	.	.	.	.	.	.	.	.	.
ASTR ALP	.	.	.	.	.	.	.	.	.	.
ACRO BOR	.	.	.	.	.	.	.	.	.	.
PYRO MIN	.	.	.	.	.	.	.	.	.	.
BETULA (juv.)	.	.	100^{1}	.	.	.	.	.	.	.
PEDI SCE	83^{14}	83^{9}	50^{2}	33^{1}	.	.	.	.	.	.
CARD NYM	.	.	.	.	.	17^{1}	25^{8}	50^{3}	33^{2}	75^{1}
CALT PAL	.	.	.	.	.	.	.	.	.	.
EPI PAL	.	.	50^{1}	18^{1}	.	.	85^{1}	63^{1}	83^{1}	100^{1}
POA/PRA	.	.	.	.	.	.	63^{2}	10^{1}	67^{2}	.
GALI TFI	.	.	.	50^{5}	.	67^{1}	100^{1}	63^{3}	.	.
RANU RPT	.	.	.	.	.	.	.	.	.	17^{1}
EQUI PAL	.	.	.	.	.	.	.	.	.	.
CALA PUR	.	.	.	.	.	67^{1}	50^{9}	13^{1}	100^{1}	50^{1}
C CANESC	.	17^{1}	.	.	18^{5}	83^{2}	88^{6}	25^{6}	100^{33}	100^{20}
RUBU ARC	50^{2}	33^{1}	25^{1}	33^{1}	.	17^{1}	88^{9}	.	67^{46}	.
SOLI VIR	.	50^{2}	100^{2}	.	.	.	.	.	.	.
MELA SIL	.	.	.	.	.	.	.	.	.	.
TRIE EUR	.	.	25^{1}	.	.	.	.	.	83^{4}	.
STEL CAL	.	.	.	17^{1}	.	.	88^{1}	.	83^{1}	.
JUNIPERUS (juv.)	.	.	.	.	.	.	.	.	.	.
EQUI FLU	.	.	.	.	.	100^{1}	63^{1}	100^{1}	100^{19}	100^{20}
C ROSTRA	.	.	.	17^{1}	100^{29}	100^{4}	100^{19}	100^{80}	67^{6}	100^{48}
POTE PAL	.	.	.	33^{8}	.	50^{11}	.	.	.	.
ERIO ANG	.	.	.	.	.	.	.	.	.	.
HIPP VUL	.	.	.	.	.	.	.	.	.	.
CALA NEG	.	.	.	.	.	.	.	.	.	.
C AQUATI	33^{1}	33^{1}	20^{1}	100^{4}	100^{22}	100^{2}	50^{9}	.	83^{7}	100^{9}
EQUI ARV	83^{2}	100^{4}	100^{76}	100^{9}	.	50^{1}	88^{1}	.	100^{2}	50^{1}
SALIX (juv.)	.	.	.	.	45^{18}	.	38^{47}	89^{36}	100^{20}	100^{25}
SALIX Z	100^{99}	100^{99}	100^{75}	100^{52}	36^{35}	100^{17}	38^{1}	50^{3}	100^{1}	75^{1}
PHLE COM	.	.	.	.	.	.	.	.	.	.
EMPE HER	.	.	.	.	.	.	.	.	.	.
VACC MYR	.	.	25^{1}	.	.	.	.	.	.	.
LYCO ANN	.	.		.	.	.	.	.	.	.
VAHL ATR	.	.	.	.	.	.	.	.	.	.
VACC ULI	.	.	.	.	.	.	.	.	.	.
DESC FLEX	.	33^{1}	.	.	.	.	13^{5}	.	.	.
PING VUL	.	.	50^{1}	.	.	.	.	.	.	.
BETU VER	.	.	.	.	.	.	75^{15}	12^{2}	.	.
GERA SIL	.	.	.	33^{1}	.	.	.	.	.	.
PEDI LAP	.	.	25^{1}	.	.	.	.	.	.	.

Table 6. Characterization of the different drainage systems distinguished in the delta lagoons.

Drainage	Water-level amplitude	Water-level at freeze-up	Rate of rise and fall of water-level	Threshold
1. Lagoons with open connection with Lake Laitaure but situated in upstream direction				
Predominantly above ground	Fairly large, as in L. Laitaure	Very low	As fast as in L. Laitaure (not so fast as in distributaries)	None or only temporary
2. Lagoons with one or two openings or with a deep, not extremely long channel towards adjacent distributary				
Predominantly above ground	Very large, as in distributary	Very low (mostly)	Fast, with very short delay	Temporary bars (only of importance at low waters)
3. Lagoons with channel connection with distributary containing threshold functioning at low waters				
Predominantly above ground but through swamp at low waters	Reduced because of higher low water-level	Higher than in adjacent distributary	Fast but delayed at high waters. Slow at low waters	Variable as to age, position and structure
4. Lagoons completely surrounded by swamps lacking distinct channel				
Above ground only at high waters, percolation through swamp at low waters	Reduced but mostly larger than in III, low-water level not fixed	Variable but usually low	Slow except at extreme high waters	Not distinct as to level
5. Lagoons surrounded by minerogenous levees, channel closed by firm sediments				
No outflow, except for percolation through firm sediments	Small, except at extreme high waters	Comparatively high	Very slow except at extreme high waters	High and stable

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ISBN 91–7210–066–4